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CHEMICAL AND BIOLOGICAL WATER QUALITY OF SELECTED STREAMS IN THE BELUGA COAL AREA, ALASKA

By

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ABSTRACT

Chemical water quality was determined in five streams during 1983 and 1984 in the Beluga coal area to determine their premining condition. In addition to field measurements, inorganic constituents, trace metal, minor element and nutrient samples were collected. Benthic invertebrates were quantitatively samples in two of the five streams, Middle and Lone Creeks, to assess biological water quality. The results show that the five streams have good chemical water quality with high concentrations of dissolved oxygen and low concentrations of dissolved inorganic constituents, trace metals, minor elements, and nutrients. All streams have calcium-bicarbonate water, except lower Bishop Creek, which is a mixed type (calcium-sodium bicarbonate water). Low alkalinity values in all five streams indicate poor acid-neutralizing capablity. Increased streamflow, surface runoff, and suspended sediment elevate total metal and nutrient concentrations in June in Bishop and Capps Creeks. Total iron concentrations are relatively high in all five streams. Benthic-invertebrate community structure shows that biological water quality in Middle and Lone Creeks is good. Benthic invertebrate standing crop exceeds 12,000 invertebrates per meter^2 and number of taxa averages 19 in both streams. Although invertebrate densities vary among sites, the composition of the taxa is similar among sites. Chironomid midges are the most abundant taxa in both streams. High invertebrate density and numerous taxa are attributed to warm summer water temperatures, light suspended sediment loads, and groundwater-maintained winter baseflow.

INTRODUCTION

Surface coal mining is proposed to begin during the 1990's in the Beluga coal area. Surface-water quality protection is a primary concern in the development of these proposed coal mines because of the highly valued fishery resources of the Chuitna River and the Beluga River and their tributaries. Planning for protection of the surface waters and their fishery resources can be enhanced through areal collection of baseline surface-water quality data prior to mining. Several studies have investigated surface-water quality in the Beluga coal area (Scully, 1981; Environmental Research and Technology, Inc. [ERT], 1984a, 1984b; Maurer and Toland, 1984). The purpose of this study is to supplement these prior studies by interpreting the second year data of the chemical water quality study and to present biological water-quality information on two streams that will be influenced by coal mining.

The specific objectives of the study are to: 1) determine baseline chemical water quality in five streams within the Beluga coal area, 2) assess biological water quality by determining the benthic invertebrate community in Middle and Lone Creek prior to mining, and 3) supplement baseline information to assess the effects of future coal mining on water quality. The emphasis of the chemical water-quality investigation is on trends in field variables, major inorganic constituents, and nutrients. Samples were collected to correspond with specific hydrologic flow conditions of early summer (June), late summer (August), early winter (December), and late winter (March). The focus of the biological water-quality investigations is to determine benthic invertebrate distribution and abundance. Benthic invertebrates were selected as biological indicators of water quality because they are relatively immobile, year-round inhabitants of streams, are sensitive to water chemistry and aquatic habitat changes, and are important food sources for fish (Cairns and Dickson, 1971).

STUDY AREA

The Beluga coal area is located in southcentral Alaska on the west side of Cook Inlet, about 80 km (50 mi) west of Anchorage (fig. 1). A detailed description of the physiography, climate, and stream characteristics is presented in Maurer and Toland, 1984. The location of chemical and biological water-quality sampling sites is shown on figure 1. Five nonglacial streams, Bishop Creek, Capps Creek, Middle Creek, Lone Creek, and the Chuitna River, were selected to obtain areal water-quality conditions in the Beluga coal area. Bishop Creek is the proposed control stream because no coal mining is planned within its watershed. All chemical water-quality sampling sites were located in the lower reaches of the streams, downstream from prospective mining. Macroinvertebrate sampling sites were located on Middle and Lone Creeks because of their proximity to a proposed surface coal mine (fig. 1). Sampling sites were selected at an upper, middle, and lower reach in Middle and Lone Creeks to assess the effects of future coal mining on invertebrate community structure.

METHODS

Chemical

Stream discharge was measured on each sampling date at the chemical water-quality sites with a Marsh-McBirney current meter according the U.S. Geological Survey methods (Carter and Davidson, 1968; Buchanan and Somers, 1969). Water temperature, dissolved oxygen concentration, and specific conductance were measured in the field with a digital 4041 Hydrolab. An Orion digital pH meter was used to measure field pH. Measurements of dissolved oxygen and pH were taken in low velocity reaches within the stream to avoid streaming effects across the membrane probes. Bicarbonate alkalinity was

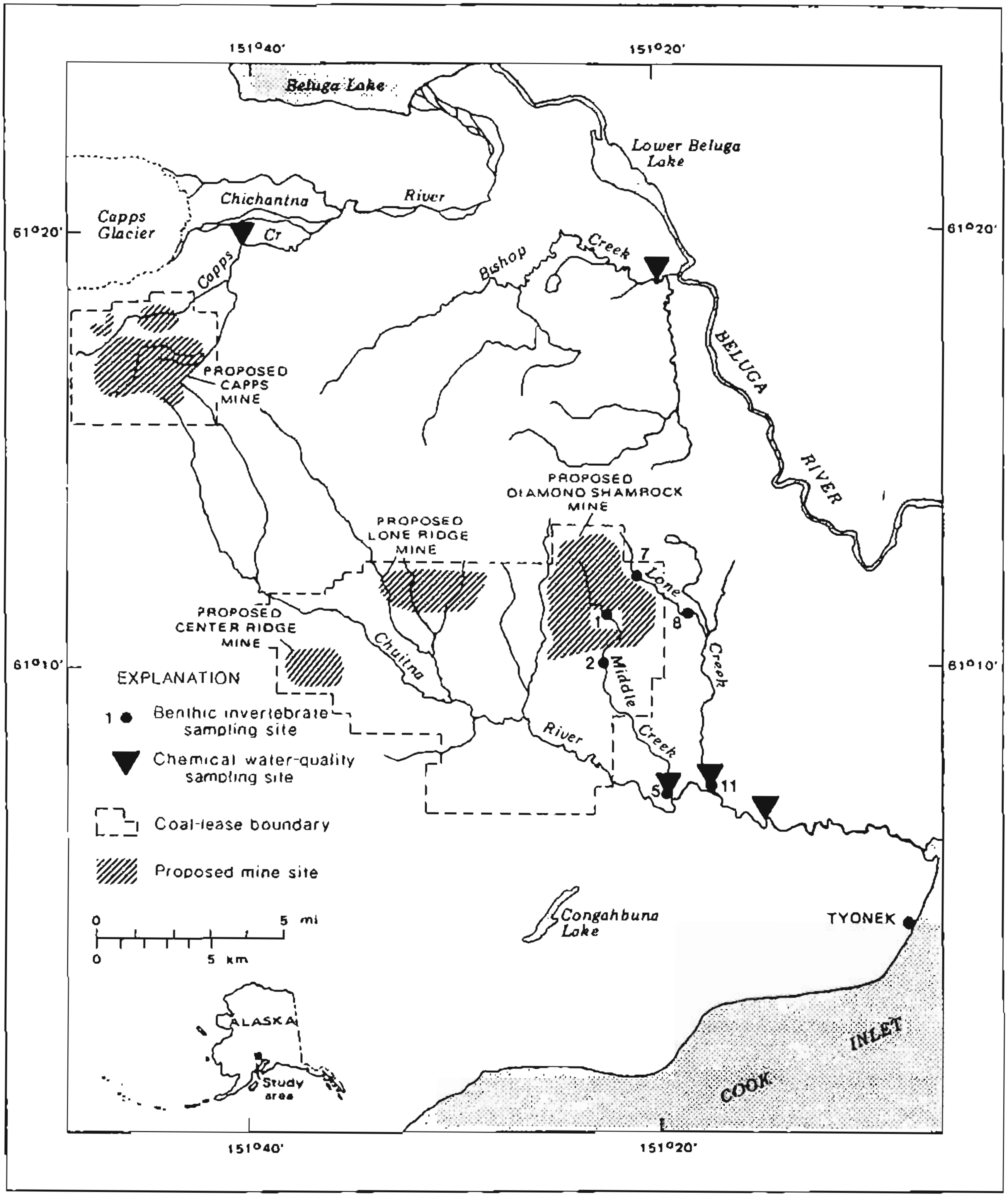

Figure 1. Location map of benthic invertebrate and chemical water-quality sampling sites, Beluga coal area, Alaska.

measured in the field by titrating an untreated 200 ml sample with 0.01639N sulfuric acid to an electrometrically determined endpoint of pH 4.5 (U.S. Environmental Protection Agency [EPA], 1983).

All water samples were collected by the grab sampling technique. Samples for major inorganic constituents and dissolved trace-metal analysis were immediately filtered through a 0.45-μm membrane filter. Total and dissolved trace-metal samples were acidified with double-distilled 70-percent nitric acid immediately after collection. Nutrient samples were untreated for total concentrations or filtered through a 0.45-μm membrane filter for dissolved concentrations in the field and frozen within eight hours of collection.

Major inorganic constituents and total and dissolved trace metal samples were analyzed by Anatec Laboratories, Inc., in Santa Rosa, California. All inorganic constituents were analyzed according to U.S. EPA (1983) or American Public Health Association (APHA) methods (1980). With the exception of boron, trace metal concentrations were measured using atomic absorption spectrophotometry according to the methods of the U.S. EPA (1983). Boron concentrations were measured colorimetrically according to the methods of Wolf, 1974. Nutrient samples were analyzed at the Alaska Department of Fish and Game laboratory in Soldotna, Alaska. Concentrations of total phosphorus and total ammonia plus organic nitrogen were analyzed on a Technicon Auto Analyzer II. Dissolved nitrite plus nitrate and dissolved ammonia were analyzed in accordance with the methods of Stainton and others (1977). Two fractions of dissolved phosphorus, total filterable phosphorus and filterable reactive phosphorus, an estimate of orthophosphate, were measured according to the methods of Eisenreich and others (1975).

Biological

Three benthic invertebrate sampling sites (upper, middle, and lower) were selected to correspond to synoptic survey sites 1, 2, and 5 in Middle Creek and 7, 8, and 11 in Lone Creek (Maurer and Toland, 1984). Site 5 and 11 are located at chemical water quality sites (fig. 1). Samples were collected over a two year period, during June and August of 1983 and 1984. Statistical analyses (Elliott, 1977) were performed on synoptic-survey invertebrate densities to estimate a suitable sample size per site in this study. The results indicated that ten samples per site in Middle Creek and three samples per site in Lone Creek were required for a standard error equal to 20 percent of the mean. Because this sampling schedule would greatly increase the time needed for sampling and analysis, the number of samples to be taken per site was compromised at four. Each stream reach was separated into four equal strata, parallel to streamflow. A stratified random sampling technique was used, that is, one sample was randomly chosen within each stratum. Habitat variables of water depth, stream width, and water temperature were measured at each site. Water velocity at the streambed was measured with a Marsh-McBirney current meter prior to sampling. Stream-substrate composition within the area of the samples was visually estimated by examining the relative percentages of boulder (>256 mm in diameter), rubble (64-256 mm in diameter), gravel (2-64 mm in diameter), and sand/silt (0.004-2.0 mm in diameter) (U.S. EPA, 1973).

A 0.6 meter high, 0.1 meter^2 cylindrical, aluminum substrate sampler was used to collect benthic invertebrates. The sides of the sampler's frame were covered with a net composed of 600-μm (pore diameter) NITEX (Nylon) mesh netting on the front side to increase water flow through the sampler and 300-μm NITEX netting on the back side and trailing collection bag. Samples were collected by working the sampler into the streambed and displacing the rocks to dislodge invertebrates. Larger rocks were examined and shrubbed to insure that all invertebrates were removed. Invertebrates were washed into the collection bag and trapped in a detachable plastic bucket at the end of the bag. Samples were preserved in the field with a solution of 70-percent ethyl alcohol and water. Rose bengal bacteriological stain was added to the solution to facilitate sorting in the laboratory.

All invertebrates were hand-picked from sample debris and stored in 70-percent ethyl alcohol in three dram vials. Insects were counted and identified to the most practical taxonomic level using keys by Usinger (1956), Jensen (1966), Smith (1968), Edmunds and others (1976), Baumann and others (1977), Wiggins (1977), and Merritt and Cummins (1978). In many cases, very small specimens could only be identified to the ordinal or family taxonomic level. Non-insect invertebrates were identified to the class or ordinal level using keys published by Pennak (1978).

Invertebrate biomass was determined in the laboratory by measuring the wet weight of all invertebrates in each benthic sample. Preserved invertebrates, the alcohol contents of the vial, and a 10-ml alcohol rinse were poured onto a tared 0.45-μm membrane filter contained in a Millipore filtering unit. A vacuum-pump was hand-operated at a pressure of 30-cm mercury for one minute to remove the excess alcohol. The invertebrates and filter were then immediately weighed on an electronic balance to the nearest 0.001 grams.

Several quantitative methods were used to analyze invertebrate samples. Insect abundance was based on density (number of invertebrates per $meter^2$). The number of taxa was determined by summing the taxonomic groups, that is, the number of identifiable insect families and other invertebrate groups, found in each sample. Invertebrate community structure was calculated using the Shannon-Weaver diversity index (H') and evenness (J') value (Poole, 1974). The formula for the Shannon-Weaver diversity index is $H' = -\sum_{i=1}^{s} p_i \log_2 p_i$, where s is the number of taxa and p_i is a proportion (total number of invertebrates of the i^{th} taxa divided by the total number of invertebrates of all taxa). Evenness is expressed as $J' = H'/H'_{maximum}$ where $H'_{maximum} = \log_2 s$ (s = number of taxa). The diversity and evenness values for stream, year, and month were calculated on pooled samples, that is, all samples within the stream, year, or month were pooled (summed) to form a single sample.

A statistical three-factor analysis of variance (Zar, 1974) was performed on invertebrate density data to determine if there are differences between streams and among sites. Prior to the analysis the density data in each sample were transformed from X to log X to approximate a normal distribution (Elliott, 1971). The probability level used in the statistical F test was $\alpha = 0.05$.

RESULTS AND DISCUSSION

Chemical Water Quality

Field variables

Streamflow was measured at each chemical water-quality site on each sampling date (fig. 2). The hydrographs show high flow during June in Bishop and Capps Creeks and the Chuitna River but little variation in streamflow in

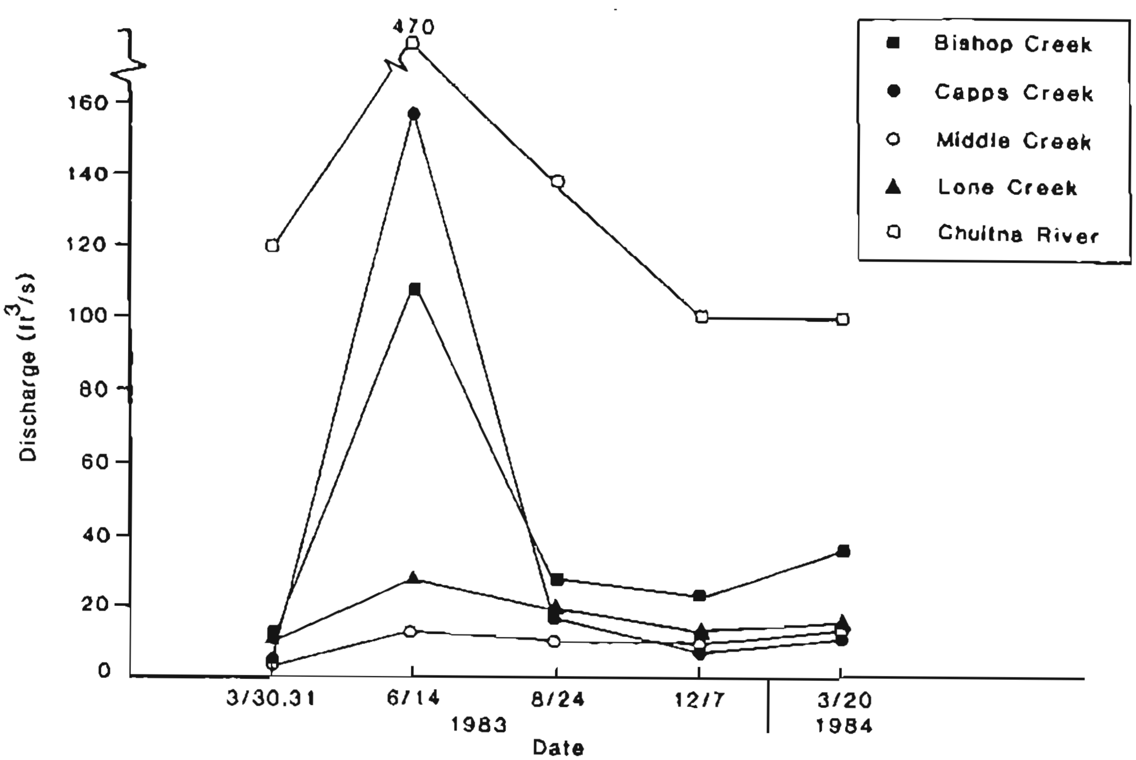

Figure 2. Stream discharge on each sampling date at chemical water-quality sites in five streams, Beluga coal area.

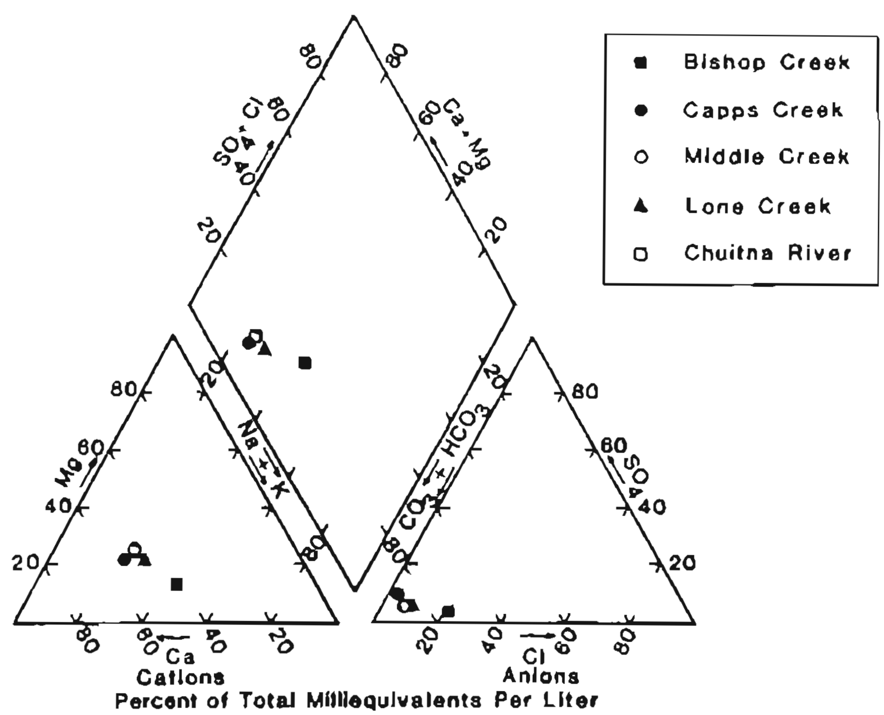

Figure 3. Trilinear diagram of water analyses for five streams in the Beluga coal area during 1983 and 1984.

Middle and Lone Creeks. Although an attempt was made to collect data during the various flow conditions, that is, winter baseflow, spring runoff, summer low flow, early winter flow, the single sampling date in June did not allow peak spring runoff to be measured in Middle and Lone Creeks. Peak spring discharge at these two streams occurs in May (ERT, 1984b). Moreover, the suspended sediment load measured in June in Middle and Lone Creeks is significantly less than in Bishop and Capps Creeks (Maurer and Toland, 1984). These observations are important because suspended sediment has a significant effect on the chemical water quality of Bishop and Capps Creeks. Streamflow measured in the Chuitna River in June represent early summer high flow because peak spring runoff normally occurs in late May or early June (USGS, 1984; 1985).

Other variables measured in the field were water temperature, specific conductance, pH, alkalinity, and dissolved oxygen concentration (appendix A). Water temperature ranged from 0°C in Bishop Creek, Middle Creek, Lone Creek, and the Chuitna River during December and March to a high of 13.8°C in the Chuitna River in August (appendix A). Capps Creek showed the least variation in water temperature. This is due to the site's higher elevation, relatively high gradient, and proximity to groundwater sources. Specific conductance is relatively low compared to other surface waters (Hem, 1970), averaging only 50 µmhos/cm at the five chemical water-quality sampling sites. Although there was relatively little change in specific conductance seasonally among the five streams, it did vary inversely with discharge. The pH averages close to 7.0 in each stream. Mean pH values show that Bishop Creek and Capps Creek are slightly acid, while Middle Creek, Lone Creek, and the Chuitna River have pH slightly above neutrality. The lowest pH, 5.85, was measured in Capps Creek.

Bicarbonate alkalinity is similar among sites. Alkalinity values, ranging from 10.5 to 46 mg/l indicate that these streams' ability to neutralize acids is poor. Alkalinity also varied inversely with discharge. Dissolved oxygen concentrations were generally near saturation in each stream. The lowest concentrations were measured in December 1982. The percent saturation of dissolved oxygen ranged from 92 to 100 percent in the summer and 78 to 100 percent in the winter.

Dissolved constituents

The concentration of major cations and anions was consistently low. The total filterable residue (dissolved solids) concentrations varied little, ranging from 44 to 61 mg/l among the five streams (appendix A). Although there was similarity in ionic composition, based on the average percentage of major ion concentrations expressed in milliequivalents per liter, Bishop Creek had a slightly different ionic composition than the other four streams (fig. 3).

Calcium is the major cation in Capps, Middle, and Lone Creeks and the Chuitna River, representing between 50 and 55 percent of the cations in these four streams. Bishop Creek, however, has equal percentages (41 percent) of calcium and sodium ions. All five streams have approximately the same percentage of potassium ions (4 percent). While Bishop Creek has a relatively low percentage (15 percent) of magnesium ions, the other four streams have similar concentrations of sodium and magnesium ions, 22 and 24 percent respectively.

Bicarbonate is the major anion in all five streams, representing approximately 86 percent of the anions. The percentage of chloride and sulfate ions averages 8 and 4 percent in Middle and Lone Creeks and the Chuitna River, and 1 and 10 percent in Capps Creek. The chloride ion concentration in Bishop Creek, representing 21 percent of the anions, was significantly higher than the other streams (fig. 3).

Based on these ionic compositions, Capps, Middle, and Lone Creeks and the Chuitna River have been classified as calcium-bicarbonate waters, while Bishop Creek has been classified as calcium-sodium bicarbonate water (fig. 3). Bishop Creek has a different ionic composition than the other four streams because it has higher percentages of sodium and chloride ions. Because the ionic composition of Bishop Creek's middle reach (Scully, 1981) does not differ appreciably from the other four streams, the source of the sodium and chloride ions may be exposed deposits of "very fine bonded plastic clay" (Barnes, 1966) which occur only along the stream's lower reach.

Silica concentrations ranged from 9.7 to 13.6 mg/l (appendix A). Dissolved silica is the result of weathering of silicate minerals and these concentrations are characteristic of surface waters (Hem, 1970). Significantly lower concentrations, however, were measured in August at all sites and this may be in part due to silica utilization by aquatic algae, particularly diatoms (Reid, 1976).

Trace metals and minor elements

The concentrations of trace metals and minor elements measured in all five streams are generally low or below detection limits (appendix B).

Concentrations of most elements do not vary significantly among streams nor do they show a distinct seasonal trend. However, total concentrations of aluminum, iron, and several of the minor trace metals and elements were relatively high or detectable in June in Bishop and Capps Creeks due to high suspended sediment loads. For example, total zinc concentrations were detectable in low concentrations, that is, <10 μg/l, but total concentrations in Capps Creek during June were 78 μg/l. Barium and strontium were measured in low concentrations in all streams. Low concentrations of these elements are typical of many surface waters (Hem, 1970). Total manganese concentrations were detectable, but were relatively low, ranging from 0.02 mg/l to 0.28 mg/l. The highest total manganese concentrations were associated with suspended sediment in Capps Creek, and the lowest concentrations occurred in the Chuitna River, where the mean concentration was <0.03 mg/l (appendix B).

Aluminum and iron were the most abundant metals measured in all five streams and seasonal trends are apparent in total aluminum and dissolved iron concentrations (fig. 4). Total aluminum concentrations generally were similar among streams but concentrations were elevated in Bishop and Capps Creeks in June, measuring 2.2 mg/l and 12.0 mg/l, respectively. The high suspended sediment load observed during the June sampling of these two streams accounts for the elevated total aluminum concentrations. Middle and Lone Creeks had similarly low aluminum concentrations throughout the sampling period.

Total iron concentrations varied little among streams (fig. 4), but were consistently the highest of all trace metals measured, ranging from 0.41 to 8.8 mg/l (appendix B). There was little seasonal variation in total concentrations among streams, except at the Capps Creek site where a

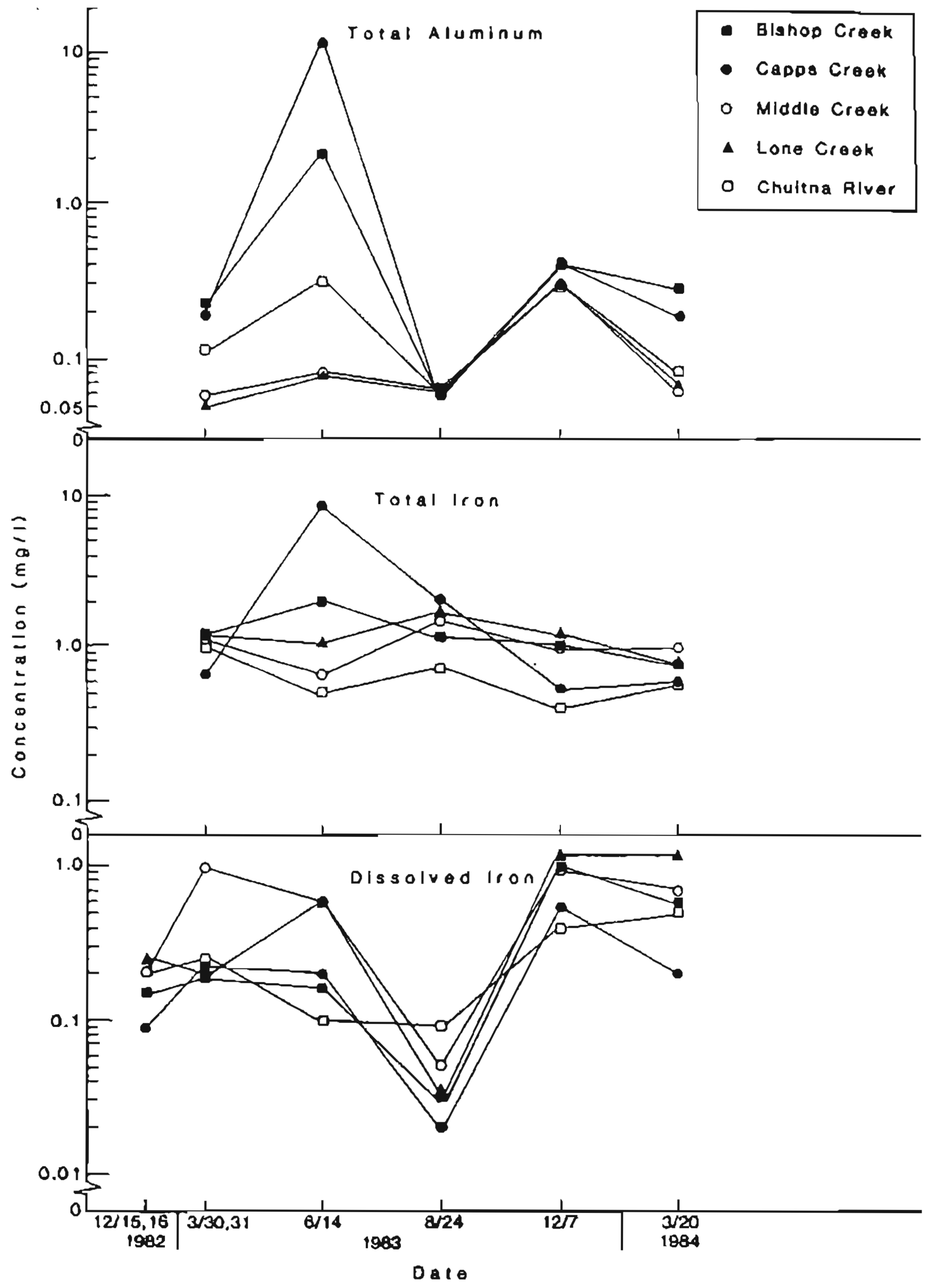

Figure 4. Seasonal variation in the concentrations of total aluminum, total iron and dissolved iron in five Beluga coal-area streams from 1982 to 1984.

concentration of 8.8 mg/l was measured in June (fig. 4). High suspended-sediment loading observed during the June sampling period in Capps Creek is the probable cause of the elevated concentration. Dissolved iron concentrations were also similar among streams, ranging from 0.02 to 1.2 mg/l (appendix A). There was seasonal variation in dissolved iron concentrations, however. The highest dissolved iron concentrations were measured in winter (December and March), while the lowest were measured in August (fig. 4). This pattern, seen in all five streams, may be due to the accumulation of organic matter and bacteria and algal growth which facilitates the precipitation of ferric hydroxide on the stream bottom (Reid, 1976), thereby reducing the concentration of dissolved iron in August.

The Chuitna River site consistently had the least seasonal variation and lowest concentration of total and dissolved iron of all sites measured (fig. 4). Total and dissolved iron concentrations at this site averaged 0.63 mg/l and 0.26 mg/l, respectively. Although total iron concentrations in Bishop, Capps, Middle, and Lone Creeks frequently exceeded the U.S. EPA criteria for protection of fresh-water aquatic life, that is, 1.0 mg/l (EPA, 1976), dissolved iron concentrations averaged less than 1.0 mg/l in all streams (fig. 4).

Nutrients

The concentration of dissolved nitrite plus nitrate nitrogen ranged from 0.012 to 0.541 mg/l in the five streams (appendix C). Dissolved nitrite plus nitrate nitrogen concentrations were relatively high in December and March and low in August in all streams (fig. 5). The concentrations measured in December and March may be due to groundwater inflow under base flow

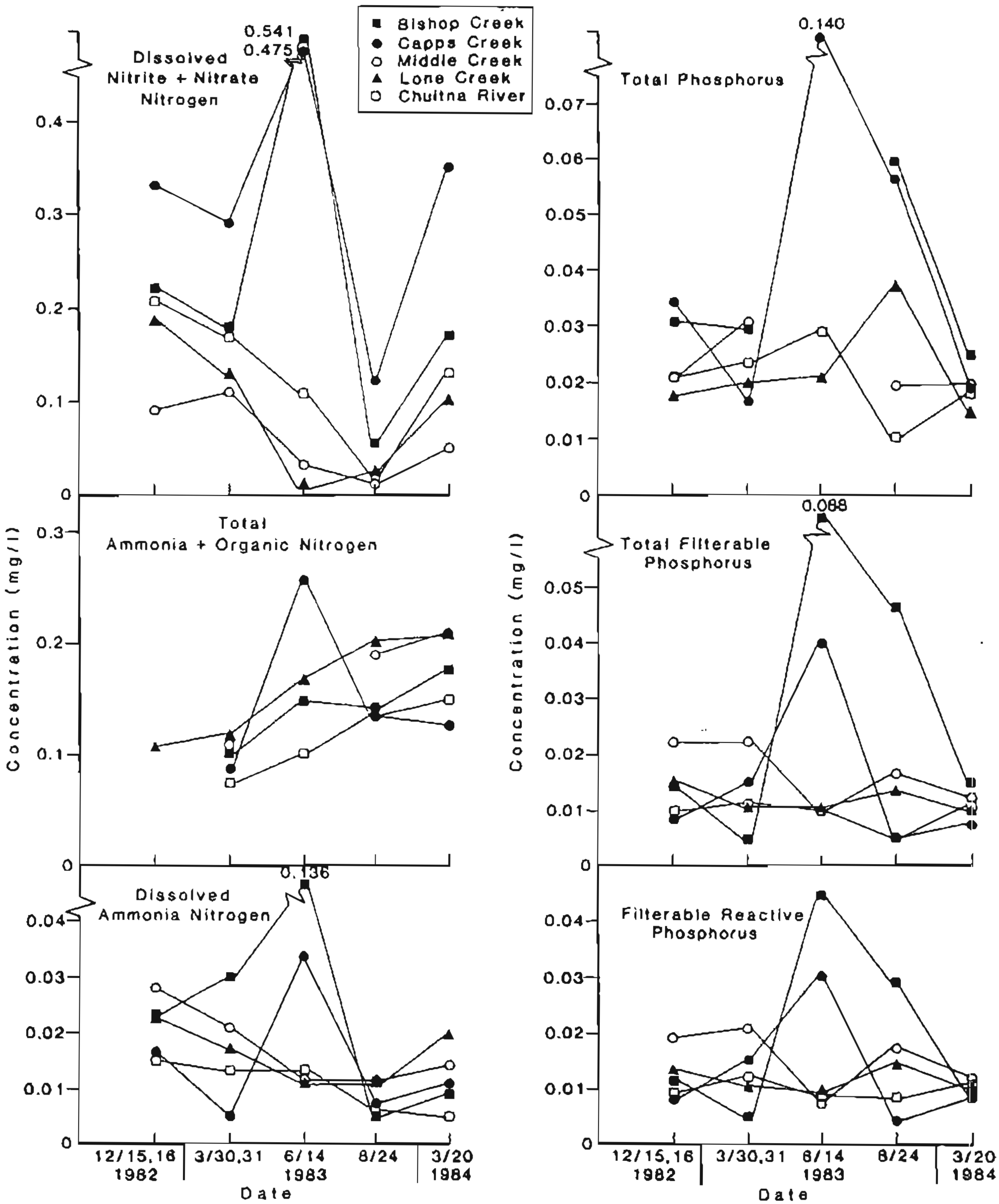

Figure 5. Seasonal variation in the concentrations of nitrogen and phosphorus fractions in five Beluga coal-area streams from 1982 to 1984.

conditions. Low concentrations in August in all five streams may be the result of nitrate utilization by algae and bacteria (Reid, 1976). Elevated concentrations in Bishop and Capps Creeks, 0.541 and 0.475 mg/l respectivly, probably result from surface runoff associated with high streamflows in June.

Total ammonia plus organic nitrogen concentrations were similar in the five streams (fig. 5). No seasonal trend was observed in these values. A relatively high concentration of 0.26 mg/l was measured in Capps Creek during June under high streamflow conditions (fig. 5). The increasing concentrations measured in all five streams from March through August 1983 may be due to organic loading from surface runoff and to periphyton production (Reid, 1976).

Dissolved ammonia nitrogen concentrations were relatively low in all five streams, ranging from 0.01 to 0.04 mg/l (appendix C). The highest concentrations, 0.136 and 0.033 mg/l in Bishop Creek and Capps Creek, respectively, were measured in June. These elevated concentrations are probably the result of increased surface runoff in June in these two streams.

The measurement of total phosphorus consists of filterable and nonfilterable forms. The measured phosphorus fractions in this study consist of total phosphorus and two filterable forms, total filterable phosphorus and filterable reactive phosphorus, which closely correspond to dissolved phosphorus and orthophosphates, respectively (APHA, 1980). Orthophosphate is the form of phosphorus utilized by plants.

Total phosphorus concentrations were similar in the five streams, ranging from 0.010 to 0.140 mg/l (fig. 5). Elevated concentrations were measured in

Capps Creek in June and August (fig. 5). Although total phosphorus concentrations were not measured in Bishop Creek in June, the elevated concentration in August suggests that June concentrations in Bishop Creek were elevated as well. Total filterable and filterable reactive phosphorus concentrations were also similar among streams and exhibited little seasonal variation, except in Bishop and Capps Creeks (fig. 5). Total filterable phosphorus concentrations ranged from 0.005 to 0.088 mg/l and filterable reactive phosphorus concentrations ranged from 0.004 to 0.044 mg/l (appendix C). The percentage of total filterable to total phosphorus was consistently high throughout the sampling period, excluding elevated concentrations in Bishop and Capps Creeks in June. It is therefore inferred that phosphorus is primarily in the dissolved form rather than the particulate form in these five streams. Similarly, the percentage of filterable reactive to total filterable phosphorus was high in all five streams (appendix C), indicating that the majority of the dissolved phosphorus is in the form of orthophosphates. These consistent concentrations of all three phosphorus fractions are probably the result of a large groundwater contribution to streamflow, which is 34 percent in Lone Creek and 32 percent in Middle Creek (ERT, 1984c).

High streamflow and high suspended sediment loads are the probable cause of elevated concentrations of all three phosphorus fractions in Bishop and Capps Creeks in June. However, elevated concentrations of all three fractions were measured in Bishop Creek during August under relatively low streamflow conditions. Although the data presented in this study are insufficient to adequately explain these elevated phosphorus concentrations, they are probably the result of biological processes.

Biological Water Quality

Invertebrate abundance

Invertebrate mean density, calculated as the number of organisms per meter^2, varied by less than 24 percent between Middle and Lone Creeks (table 1). The mean density was 12,085 invertebrates per meter^2 in Middle Creek and 15,806 invertebrates per meter^2 in Lone Creek. The mean density was approximately 26 percent higher in 1983 in both streams. Although June and August mean invertebrate densities were virtually the same in Middle Creek, the June density was two times greater than the August density in Lone Creek (table 1). Generally, there was a progressive decrease in density from the upper (headwater) site to the lower site in Lone Creek (fig. 6). The pattern in invertebrate density differed somewhat in Middle Creek, with relatively high density at the upper and middle site and low density at the lower site (fig. 6).

The invertebrate densities enumerated in this study are substantially higher than those found in Scully (1981) and ERT (1984a). These differences are probably the result of different sampling methodologies. Artificial substrates and a dip net technique was used in the Scully study and a Surber sampler was used in the ERT study. It is felt that the completely enclosed substrate sampler and smaller net mesh size (300-µm) resulted in higher densities in this study. In addition, the August densities found in this study are considerably higher than those in our August 1982 synoptic survey (Maurer and Toland, 1984). This is probably due to the many microhabitats sampled in 1983 which included deep runs and pools as well as riffles. In the present study the only habitats sampled were riffle and shallow runs, which typically have higher invertebrate densities than pools (Hynes, 1970).

Table 1. Mean invertebrate density (numbers per meter^2), mean biomass (grams per meter^2), Shannon-Weaver diversity, evenness, and mean number of taxa in Middle and Lone Creeks by stream, month, and year. n = number of samples. A 95% confidence interval is shown for each mean value of density and biomass. Diversity and evenness values were calculated on the basis of pooled samples.

	MIDDLE CREEK	LONE CREEK
Density (no./m^2)		
overall (n = 48)	12085 ± 2389	15806 ± 4032
month (n = 24)		
June	12330 ± 4269	21055 ± 7202
August	11841 ± 2784	10557 ± 3454
year (n = 24)		
1983	14008 ± 4470	17944 ± 7516
1984	10162 ± 2152	13668 ± 3983
Biomass (gm/m^2)		
overall (n = 48)	8.77 ± 0.91	13.40 ± 2.17
month (n = 24)		
June	9.62 ± 1.59	17.50 ± 3.47
August	7.92 ± 0.98	9.30 ± 1.77
year (n = 24)		
1983	9.00 ± 1.49	14.67 ± 3.74
1984	8.54 ± 1.23	12.13 ± 2.63
Diversity (H')		
overall (n = 48)	2.88	2.57
month (n = 24)		
June	2.13	1.71
August	2.99	3.26
year (n = 24)		
1983	2.79	2.44
1984	2.83	2.67
Evenness		
overall (n = 48)	0.58	0.52
month (n = 24)		
June	0.44	0.36
August	0.61	0.66
year (n = 24)		
1983	0.56	0.50
1984	0.57	0.54
Number of Taxa		
overall (n = 48)	19	19
month (n = 24)		
June	17	17
August	22	22
year (n = 24)		
1983	20	19
1984	19	20

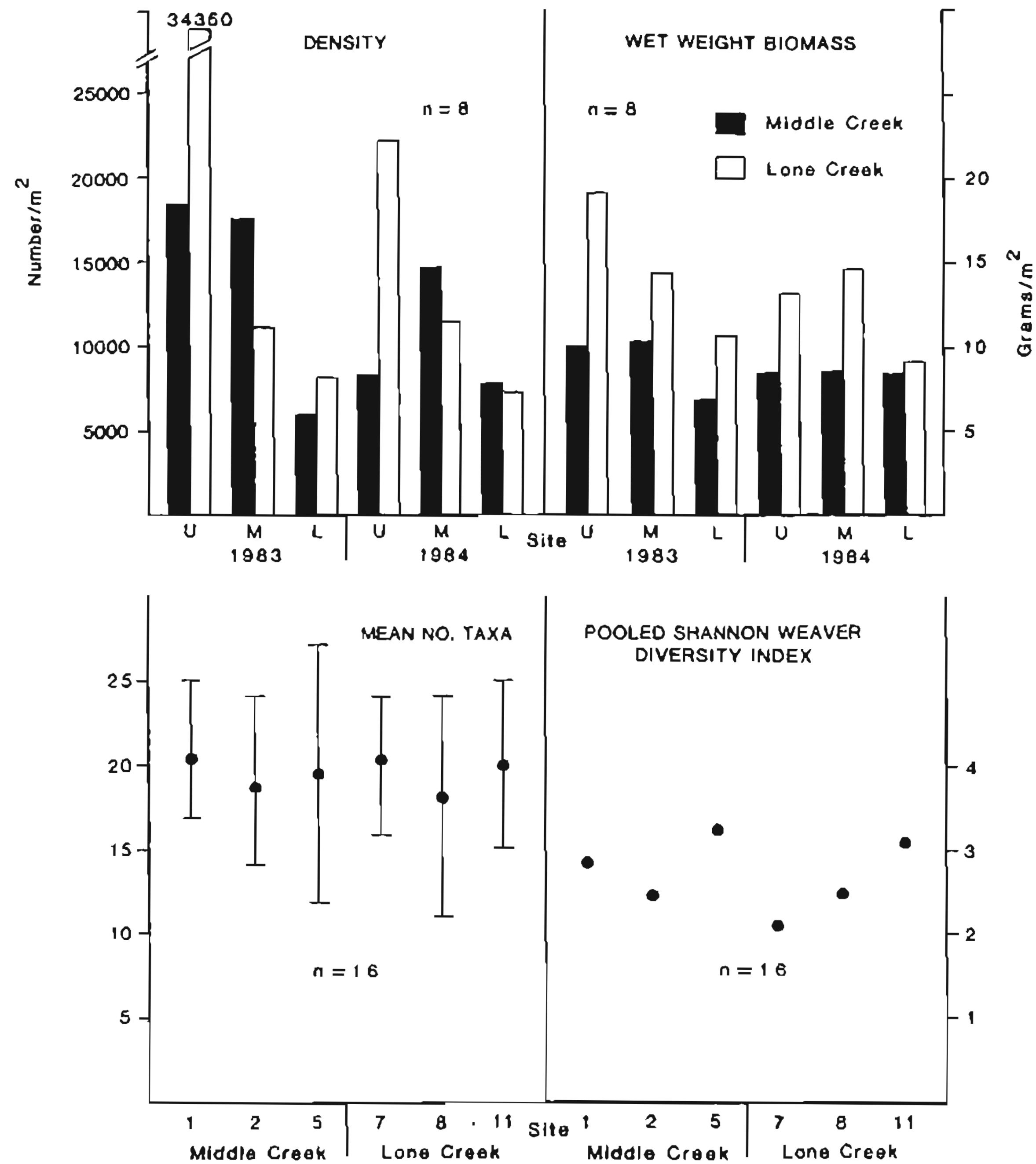

Figure 6. Density, wet weight biomass, mean number of taxa and diversity of benthic invertebrate communities at sites in Middle and Lone Creeks, Beluga coal area, during 1983 and 1984. U = upper site, M = middle site and L = lower site. Site 1, 2, and 5 in Middle Creek and site 7, 8, and 11 in Lone Creek correspond to the upper, middle, and lower site in their respective stream. *n* = number of samples.

Despite density differences, the mean number of taxa collected in this study were similar to that of past studies.

A three-factor analysis of variance (ANOVA, Zar, 1974) was performed on the invertebrate density data to determine if differences among streams (Middle vs. Lone), sites, (upper, middle, lower), and dates (June 1983, August 1983, June 1984, August 1984) are statistically significant. The results of the ANOVA indicate no significant difference between streams, a highly significant difference among sites, and a significant difference among dates (appendix E). This statistical test substantiates the relationships summarized on table 1 and figure 6. The only significant interaction is between stream and site, that is, mean invertebrate density of a stream is dependent on site (appendix E). The interaction of stream and date was nearly significant (calculated $F = 2.74$ versus critical $F = 2.76$), due to high June densities in Lone Creek.

Diversity and evenness values were slightly higher in Middle Creek. The overall diversity values, calculated from pooled samples, were 2.88 in Middle Creek and 2.57 in Lone Creek (table 1). The low to moderate numerical values in both streams indicate a fairly uneven distribution of taxa in samples (appendix D). There was no difference between years but values were higher in August, due to an increase in the number of taxa. The number of taxa ranged from 11 to 27, and averaged 19 in both streams. Generally, the highest number of taxa occurred at the upper sites in both streams. The lowest number of taxa occurred at the middle site in Lone Creek, but there was no distinct trend in Middle Creek.

Invertebrate biomass was higher in Lone Creek, averaging 13.40 grams per meter^2 in Lone Creek and 8.77 grams per meter^2 in Middle Creek (table 1). Biomass in Middle Creek did not vary appreciably between the June and August sampling period. Biomass in Lone Creek, however, was greater in June than in August by an average of 8.20 grams per meter^2 (table 1). This increase in June in Lone Creek is due to higher biomass at the upper site (site 7) and the middle site (site 8) (appendix F). Generally, there was less variability in biomass than in density (fig. 6).

Invertebrate composition

Five insect orders and six major groups of non-insect invertebrates were found at all sites. Diptera (true flies), predominantly chironomid midges and blackflies, were the most abundant invertebrates and represented 66 percent of the total invertebrate composition in Middle Creek and 73 percent in Lone Creek (fig. 7). Moreover, Diptera represented 80 percent of the total composition in June, but only 50 percent in August. As a result, the percentages of the other invertebrate groups were two to three times greater in August with Plecoptera having the greatest increase. These increases are due to the appearance of early instars of nemourid and capniid stoneflies and heptageniid mayflies. The decrease in the number of Diptera is probably due to pupation and emergence of midges and blackflies during the summer.

Ephemeroptera (mayflies) was the second most abundant invertebrate group, averaging approximately 12 percent of a sample in both streams. Non-insect invertebrates represented approximately 8 percent of the invertebrate composition, with Oligochaeta (aquatic earthworms) and Acarina (aquatic mites) the most abundant taxa. Plecoptera (stoneflies) and Trichoptera (caddisflies)

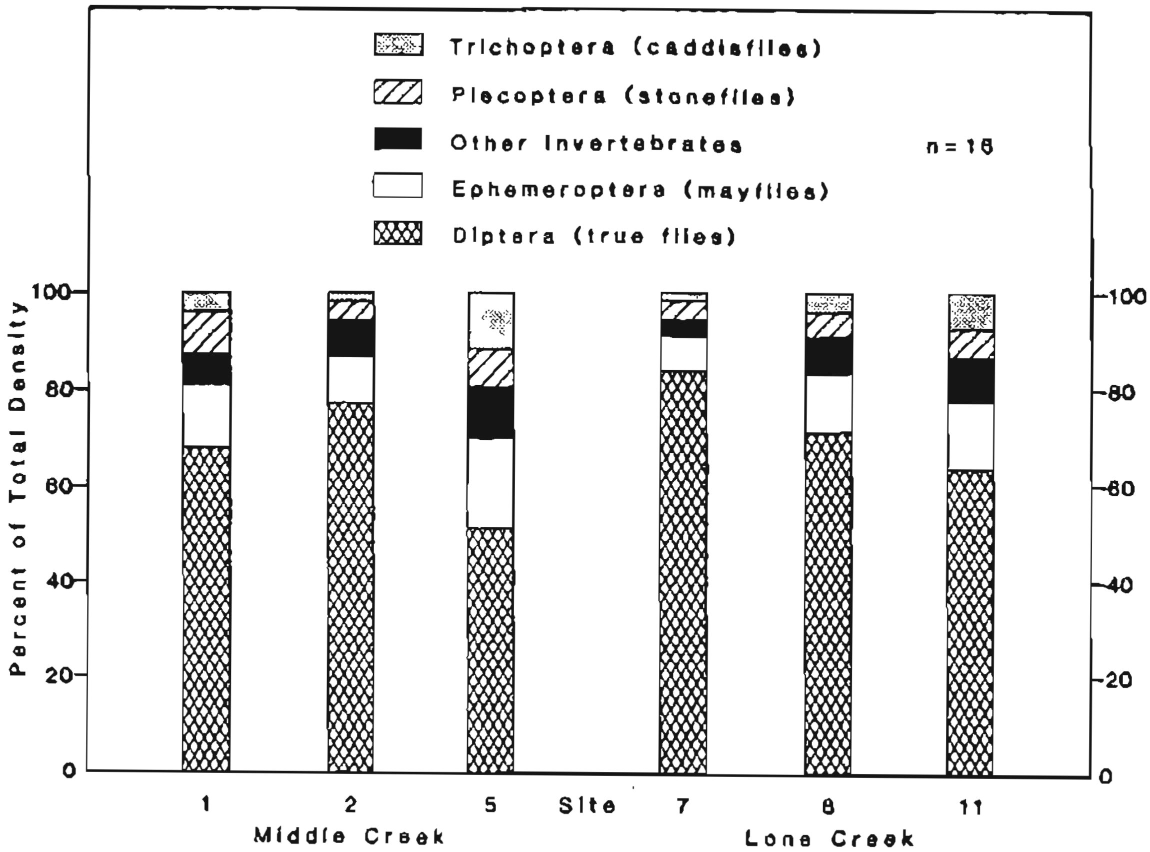

Figure 7. Percent composition (based on density) of benthic invertebrates at sites in Middle Creek and Lone Creek, Beluga coal area, during 1983 and 1984. *n* = number of samples.

averaged approximately 6 percent of the total composition. Capniid and nemourid stoneflies and glossosomatid caddisflies were the most abundant taxa in their respective groups (appendix D).

The relative distribution of invertebrate taxa, based on invertebrate density by percent, was similar among sites in Middle and Lone Creeks (fig. 7). Taxa were more evenly distributed at the lower sites of each stream, that is, site 5 in Middle Creek and site 11 in Lone Creek, because there were fewer dipteran flies present. As a result, diversity and evenness values were higher at these two sites (appendix D).

Benthic ecology

Invertebrate community structure, that is invertebrate abundance and composition, is the result of the inherent physical, chemical, and biological conditions in Middle and Lone Creeks. The most important physical factor is climate which affects the aquatic-riparian habitat to such an extent that invertebrate density and taxa are characteristic of temperate, rather than subarctic streams. The climate is moderated by Cook Inlet and both streams have a southern aspect and low gradient which raises water temperature above 13°C during the summer. Streamflow is relatively stable because the groundwater contribution to streamflow exceeds 30 percent in both stream (ERT, 1984c). Therefore, stream substrates probably do not freeze during winter and erosional processes are not significant due to stable streambanks and low stream gradient. Relatively stable streamflow also results in very stable substrates.

The chemical water quality of these streams is good. Dissolved oxygen concentrations are consistently high. Suspended sediment, trace metal, and dissolved solid concentrations are quite low and no concentrations are high enough to inhibit the invertebrate community.

There is also an abundant and varied food supply in Middle and Lone Creeks. The majority of invertebrates present in these streams, especially mayflies and midges, feed on periphyton and organic detritus (Merritt and Cummins, 1978). Blackflies strain fine particulate organic matter from the water column and several stonefly taxa shred coarse organic matter such as leaves and grasses. Although most caddisflies collect detritus, limnephilid caddisflies were observed scavenging salmon carcasses on the streambed. Thus, these taxa fill more than one trophic level within the invertebrate community.

The similarity in physical factors, water chemistry characteristics, and aquatic-riparian habitat in Middle and Lone Creeks produce a comparable invertebrate community. There were, however, several major habitat differences among sites (appendix G). The habitat at the lower site in both streams consisted of a run with large substrate size, and shading from a mixed conifer-deciduous canopy. The upper sites and middle site on Lone Creek had similar habitat features: a riffle with a rubble-gravel substrate and shrub-grass riparian vegetation. The middle site in Middle Creek was different from all other sites in that it had very shallow riffles, small rubble-size substrate, and a riparian vegetation consisting entirely of grasses. Although only minor differences in invertebrate community structure occurred among sites, relatively high invertebrate densities and numerous taxa at upper sites may be due to stable groundwater flow and optimal substrate size for invertebrate colonization.

Invertebrate abundance and composition are appropriate variables for determining the biological water quality of these streams. Both streams have taxa typical of unpolluted, cold-water streams with eroding-type substrates (Hynes, 1974). Invertebrate density is relatively high but highly variable as well. Stream-wide, mean densities are probably overestimated because riffle and shallow run habitats, which normally have higher densities than pool habitats (Hynes, 1970), were the only areas sampled. The pool/riffle ratios (ERT, 1984a) and the presence of beaver ponds indicate that pool habitats are more common in these streams. Based on the densities found in the synoptic survey (Maurer and Toland, 1984), where pool and deep run habitats were sampled, the mean invertebrate density among sites still averages approximately 7000 invertebrates per meter^2. Therefore, these relative high densities, with moderate biomass and numerous taxa, indicate a highly productive benthic invertebrate community.

CONCLUSIONS

Chemical water quality is good and very similar in Bishop, Capps, Middle, and Lone Creeks, and the Chuitna River. These streams have high concentrations of oxygen and low concentrations of dissolved solids, trace metals, and nutrients. Lower Bishop Creek has a slightly different ionic composition than the other four streams due to higher sodium and chloride ion concentrations. The elevated concentrations of trace metals and nutrients in Bishop and Capps Creeks that occur in June are the result of high streamflow, surface runoff, and suspended sediment.

Biological water quality is good in Middle and Lone Creeks. The benthic invertebrate community is characterized by relatively high density, moderate biomass, and numerous taxa. The representative taxa are typically found in well-oxygenated, clear-water streams. Invertebrate composition is dominated by chironomid midges and blackflies. Although aquatic habitat differences produce invertebrate density differences among sites, the invertebrate community structure is similar between streams.

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Appendix A. Field variables and major inorganic constituents of Beluga water-quality samples.

	Time	Streamflow, instantaneous (cfs)	Specific conductance (umhos at 25°C)	pH (units)	Water temperature (°C)	Silica, dissolved SiO_2 (mg/l)	Oxygen, dissolved (mg/l)	Oxygen, dissolved (percent saturation)	Calcium, dissolved (mg/l as Ca)	Magnesium, dissolved (mg/l as Mg)
Bishop Creek										
12-15-82	0935	15	33	7.30	-0.1	7.5	11.3	78	4.4	1.0
03-30-83	1230	13	61	6.85	-0.1	14	12.2	86	5.9	1.3
06-14-83	0910	108	24	6.80	10.5	8.1	10.2	92	2.4	0.58
08-24-83	0940	28	60	7.25	10.1	1.4	11.8	100	5.5	1.3
12-07-83	1115	[a]23	50	6.55	-0.2	14	15.2	100	4.6	0.95
03-20-84	0930	35	45	6.75	-0.1	13	13.3	91	4.4	0.94
Capps Creek										
12-15-82	1225	8.8	48	6.90	0.5	6.9	12.4	88	4.9	1.2
03-30-83	1420	5.2	57	7.25	1.1	15	13.8	99	7.3	1.7
06-14-83	1110	157	10	5.85	5.0	7.1	12.0	96	2.1	0.44
08-24-83	1105	16	39	6.95	8.2	1.4	12.5	100	5.6	1.2
12-07-83	1250	[b]7.0	52	6.65	-0.4	13	15.8	100	6.0	1.4
03-20-84	1100	[b]12	53	7.05	0.1	15	15.2	100	6.3	1.5
Middle Creek										
12-16-82	1225	6.9	59	7.60	0	13	12.7	88	5.0	1.7
03-31-83	1410	4.3	77	6.85	0.2	19	14.2	100	8.9	2.2
06-14-83	1350	13	51	7.35	12.3	12	9.9	94	5.1	1.4
08-24-83	1220	9.7	64	6.95	10.1	1.6	12.0	100	8.0	1.9
12-07-83	1535	9.4	55	6.85	-0.3	14	15.9	100	6.4	1.7
03-20-84	1230	13	46	6.85	-0.3	15	15.4	100	5.4	1.4
Lone Creek										
12-16-82	1100	16	58	7.20	-1.0	12	12.9	89	4.1	1.4
03-31-83	1150	9.6	66	7.10	0	16	14.1	99	7.8	1.8
06-14-83	1515	28	47	7.35	13.7	6.1	9.5	92	5.2	1.3
08-24-83	1320	20	65	7.25	11.1	0.95	11.6	100	8.0	1.7
12-07-83	1445	13	59	6.85	-0.2	16	16.3	100	6.6	1.5
03-20-84	1350	14	52	6.90	-0.3	16	15.6	100	5.7	1.4
Chuitna River										
12-16-82	0900	[c]100	42	7.00	-1.0	26	12.5	86	2.9	1.1
03-31-83	1100	[c]120	57	7.20	0.1	16	14.3	100	8.1	2.2
06-14-83	1700	[c]470	21	7.30	11.3	7.7	10.9	100	2.5	0.66
08-24-83	1445	139	47	8.10	13.8	2.1	11.6	100	7.0	1.6
12-07-83	1400	[d]100	44	6.15	-0.3	16	15.9	100	5.8	1.5
03-20-84	1450	[d]100	43	7.10	-0.3	14	15.6	100	5.2	1.5

[a]Estimate only, ice on probe head.
[b]U.S. Geological Survey (1985, p. 180).
[c]U.S. Geological Survey (1984, p. 159).
[d]U.S. Geological Survey (1985, p. 182).

	Sodium, dissolved (mg/l as Na)	Potassium, dissolved (mg/l as K)	Iron, dissolved (mg/l as Fe)	Manganese, dissolved (mg/l as Mn)	Chloride, dissolved (mg/l as Cl)	Fluoride, dissolved (mg/l as F)	Alkalinity, bicarbonate (field) (mg/l as HCO_3)	Sulfate, dissolved (mg/l as SO_4)	Residue, total filtrable at 180°C (mg/l)
Bishop Creek									
12-15-82	5.0	0.55	0.16	0.023	4.2	< 0.10	27	1.0	54
03-30-83	7.6	0.76	0.19	0.038	5.7	< 0.1	31	1.1	69
06-14-83	2.5	0.34	0.17	0.023	1.1	< 0.10	13.5	2	35
08-24-83	6.2	0.55	0.033	0.025	6.3	0.10	26	2.7	23
12-07-83	5.1	0.45	1.0	0.04	3.9	0.12	22	< 2	46
03-20-84	4.6	0.56	0.6	0.028	4.3	< 0.1	22.5	< 2	50
Capps Creek									
12-15-82	2.5	0.57	0.088	0.022	< 1.0	< 0.10	31	2.0	49
03-30-83	3.6	0.63	0.23	0.035	< 1.0	< 0.1	36	1.5	63
06-14-83	0.97	0.37	0.20	0.054	< 1.0	< 0.10	10.5	2.2	27
08-24-83	2.2	0.41	0.020	0.078	< 1	< 0.10	23.5	2.7	26
12-07-83	2.6	0.44	0.55	0.05	< 1	0.10	42.5	3.8	39
03-20-84	2.8	0.53	0.2	0.046	1.8	< 0.1	29.5	< 2	60
Middle Creek									
12-16-82	3.3	0.59	0.21	0.016	1.4	< 0.10	36.5	1.9	85
03-31-83	4.7	0.77	0.95	0.035	1.9	< 0.1	46	< 1.0	80
06-14-83	3.1	0.54	0.59	0.022	< 1.0	< 0.10	29	2	52
08-24-83	3.5	0.55	0.051	0.045	1.6	< 0.10	37.5	3.3	42
12-07-83	3.3	0.42	1.0	0.07	1.5	< 0.1	31	< 2	41
03-20-84	3.1	0.51	0.7	0.002	1.9	< 0.1	27	< 2	40
Lone Creek									
12-16-82	4.0	0.74	0.25	0.023	2.4	< 0.10	35.5	1.8	56
03-31-83	4.4	0.89	0.19	0.042	2.8	< 0.1	40.5	< 1.0	77
06-14-83	3.0	0.60	0.61	0.049	1.1	< 0.10	28	2.1	49
08-24-83	4.2	0.64	0.035	0.054	2.4	< 0.10	34	3.3	48
12-07-83	4.4	0.55	1.2	0.08	2.2	< 0.1	32.5	< 2	44
03-20-84	3.6	0.64	1.2	0.034	2.9	< 0.1	28	< 2	90
Chuitna River									
12-16-82	2.0	0.40	0.21	0.012	2.4	< 0.10	33.5	< 1.0	47
03-31-83	4.1	0.71	0.26	0.013	1.4	< 0.1	39	1.6	84
06-14-83	1.5	0.32	0.10	0.009	< 1.0	< 0.10	14	2	33
08-24-83	2.8	0.46	0.087	< 0.02	1	< 0.10	30	2.9	34
12-07-83	3.2	0.44	0.41	< 0.03	1.1	< 0.1	27	< 2	38
03-20-84	2.7	0.56	0.5	< 0.002	2.4	< 0.1	24.5	< 2	100

Appendix B. Minor-element analysis of Beluga water-quality samples.

	Time	Streamflow, instan- taneous (cfs)	Aluminum, total (ug/l as Al)	Aluminum, dissolved (ug/l as Al)	Antimony, total (ug/l as Sb)	Antimony, dissolved (ug/l as Sb)	Arsenic, total (ug/l as As)	Arsenic, dissolved (ug/l as As)	Barium, total (ug/l as Ba)	Barium, dissolved (ug/l as Ba)
Bishop Creek										
03-30-83	1230	13	230	-	< 2	-	< 2	-	69	-
06-14-83	0910	108	2200	320	3	< 2	4	< 2	30	20
08-24-83	0940	28	< 60	-	< 2	-	< 2	-	420	-
12-07-83	1115	[a]23	400	-	< 10	-	< 2	-	20	-
03-20-84	0930	35	270	-	< 5	-	< 2	-	10	-
Capps Creek										
03-30-83	1420	5.2	190	-	< 2	-	< 2	-	77	-
06-14-83	1110	157	12,000	300	9	< 2	16	< 2	140	20
08-24-83	1105	16	< 60	-	< 2	-	< 2	-	420	-
12-07-83	1250	[b]7.0	400	-	< 10	-	< 2	-	20	-
03-20-84	1100	[b]12	190	-	< 5	-	< 2	-	30	-
Middle Creek										
03-31-83	1410	4.3	58	-	< 2	-	< 2	-	45	-
06-14-83	1350	13	79	20	< 2	< 2	< 2	< 2	20	30
08-24-83	1220	9.7	< 60	-	< 2	-	< 2	-	420	-
12-07-83	1535	9.4	300	-	< 10	-	< 2	-	< 10	-
03-20-84	1230	13	60	-	< 5	-	< 2	-	10	-
Lone Creek										
03-31-83	1150	9.6	52	-	< 2	-	< 2	-	53	-
06-14-83	1515	28	75	41	< 2	< 2	< 2	< 2	20	20
08-24-83	1320	20	< 60	-	< 2	-	< 2	-	420	-
12-07-83	1445	13	300	-	< 10	-	< 2	-	10	-
03-20-84	1350	14	65	-	< 5	-	< 2	-	10	-
Chuitna River										
03-31-83	1100	[c]120	120	-	< 2	-	< 2	-	45	-
06-14-83	1700	[c]470	300	41	< 2	< 2	< 2	< 2	10	20
08-24-83	1445	139	< 60	-	< 2	-	< 2	-	420	-
12-07-83	1400	[d]100	300	-	< 10	-	< 2	-	< 10	-
03-20-84	1450	[d]100	80	-	< 5	-	< 2	-	5	-

[a]Estimate only, ice on probe head.
[b]U.S. Geological Survey (1985, p. 180).
[c]U.S. Geological Survey (1984, p. 159).
[d]U.S. Geological Survey (1985, p. 182).

Appendix B. (cont.)

	Beryllium, total (ug/l as Be)	Beryllium, dissolved (ug/l as Be)	Boron, total (ug/l as B)	Boron, dissolved (ug/l as B)	Cadmium, total (ug/l as Cd)	Cadmium, dissolved (ug/l as Cd)	Chromium, total (ug/l as Cr)	Chromium, dissolved (ug/l as Cr)	Copper, total (ug/l as Cu)	Copper, dissolved (ug/l as Cu)
Bishop Creek										
03-30-83	< 2	-	480	-	< 0.5	-	< 4	-	< 5	-
06-14-83	< 0.2	< 0.2	70	50	< 0.5	< 0.5	< 5	< 5	< 5	< 5
08-24-83	< 1	-	< 0.05	-	< 0.5	-	< 5	-	< 5	-
12-07-83	< 1	-	0.14	-	< 0.5	-	< 2	-	< 3	-
03-20-84	< 0.2	-	< 50	-	< 0.5	-	< 5	-	< 5	-
Capps Creek										
03-30-83	< 2	-	74	-	< 0.5	-	< 4	-	< 5	-
06-14-83	< 0.2	< 0.2	170	70	< 0.5	< 0.5	14	< 5	20	< 5
08-24-83	< 1	-	< 0.05	-	< 0.5	-	< 5	-	< 5	-
12-07-83	< 1	-	0.06	-	< 0.5	-	< 2	-	< 3	-
03-20-84	< 0.2	-	< 50	-	< 0.5	-	< 5	-	< 5	-
Middle Creek										
03-31-83	< 2	-	< 50	-	< 0.5	-	< 4	-	< 5	-
06-14-83	< 0.2	< 0.2	50	50	< 0.5	< 0.5	< 5	< 5	< 5	[e]8
08-24-83	< 1	-	< 0.05	-	< 0.5	-	< 5	-	< 5	-
12-07-83	< 1	-	0.05	-	< 0.5	-	< 2	-	< 3	-
03-20-84	< 0.2	-	< 50	-	< 0.5	-	< 5	-	< 5	-
Lone Creek										
03-31-83	< 2	-	< 50	-	< 0.5	-	< 4	-	< 5	-
06-14-83	< 0.2	< 0.2	50	50	< 0.5	< 0.5	< 5	< 5	< 5	< 5
08-24-83	< 1	-	< 0.05	-	< 0.5	-	< 5	-	< 5	-
12-07-83	< 1	-	0.07	-	< 0.5	-	< 2	-	4	-
03-20-84	< 0.2	-	< 50	-	< 0.5	-	< 5	-	< 5	-
Chuitna River										
03-31-83	< 2	-	< 50	-	< 0.5	-	< 4	-	< 5	-
06-14-83	< 0.2	< 0.2	< 50	< 50	< 0.5	< 0.5	< 5	< 5	< 5	< 5
08-24-83	< 1	-	< 0.05	-	< 0.5	-	< 5	-	< 5	-
12-07-83	< 1	-	< 0.05	-	< 0.5	-	< 2	-	< 3	-
03-20-84	< 0.2	-	< 50	-	< 0.5	-	< 5	-	< 5	-

[e]Contamination suspected.

Appendix B. (cont.)

	Iron, total (ug/l as Fe)	Iron, dissolved (ug/l as Fe)	Lead, total (ug/l as Pb)	Lead, dissolved (ug/l as Pb)	Manganese, total (ug/l as Mn)	Manganese, dissolved (ug/l as Mn)	Mercury, total (ug/l as Hg)	Mercury, dissolved (ug/l as Hg)	Nickel, total (ug/l as Ni)	Nickel, dissolved (ug/l as Ni)
Bishop Creek										
03-30-83	1300	-	< 5	-	52	-	< 0.05	-	< 5	-
06-14-83	2000	f13	< 5	< 5	60	25	< 0.05	< 0.05	< 5	< 5
08-24-83	1200	-	7	-	99	-	< 0.05	-	< 5	-
12-07-83	1000	-	< 5	-	40	-	< 0.05	-	< 5	-
03-20-84	770	-	< 2	-	30	-	0.5	-	< 5	-
Capps Creek										
03-30-83	680	-	< 5	-	43	-	< 0.05	-	< 5	-
06-14-83	8800	f98	< 5	< 5	280	35	0.1	< 0.05	15	< 5
08-24-83	2100	-	< 2	-	190	-	< 0.05	-	< 5	-
12-07-83	550	-	< 5	-	50	-	< 0.05	-	< 5	-
03-20-84	630	-	< 2	-	53	-	< 0.5	-	< 5	-
Middle Creek										
03-31-83	1200	-	< 5	-	44	-	< 0.05	-	5.7	-
06-14-83	670	f130	13	< 5	35	35	< 0.05	< 0.05	< 5	< 5
08-24-83	1500	-	< 2	-	66	-	< 0.05	-	< 5	-
12-07-83	1000	-	< 5	-	70	-	< 0.05	-	< 5	-
03-20-84	1000	-	< 2	-	42	-	< 0.5	-	< 5	-
Lone Creek										
03-31-83	1200	-	< 5	-	57	-	< 0.05	-	< 5	-
06-14-83	1100	f40	< 5	< 5	55	55	< 0.05	< 0.05	< 5	< 5
08-24-83	1700	-	< 2	-	84	-	< 0.05	-	< 5	-
12-07-83	1200	-	< 5	-	80	-	< 0.05	-	< 5	-
03-20-84	770	-	< 2	-	60	-	0.5	-	< 5	-
Chuitna River										
03-31-83	930	-	< 5	-	22	-	< 0.05	-	< 5	-
06-14-83	500	f170	< 5	< 5	35	15	< 0.05	< 0.05	< 5	< 5
08-24-83	710	-	< 2	-	< 20	-	< 0.05	-	< 5	-
12-07-83	410	-	< 5	-	< 30	-	< 0.05	-	< 5	-
03-20-84	600	-	< 2	-	22	-	0.5	-	< 5	-

[f] Low values suspected. See Appendix A for dissolved iron values.

Appendix B. (cont.)

	Selenium, total (ug/l as Se)	Selenium, dissolved (ug/l as Se)	Silver, total (ug/l as Ag)	Silver, dissolved (ug/l as Ag)	Strontium, total (ug/l as Sr)	Strontium, dissolved (ug/l as Sr)	Titanium, total (ug/l as Ti)	Titanium, dissolved (ug/l as Ti)	Vanadium, total (ug/l as V)	Vanadium, dissolved (ug/l as V)	Zinc, total (ug/l as Zn)	Zinc, dissolved (ug/l as Zn)
Bishop Creek												
03-30-83	< 4	-	< 2	-	220	-	< 50	-	< 10	-	4.8	-
06-14-83	< 2	< 2	< 2	< 2	70	65	140	< 20	< 10	< 10	9.3	15
08-24-83	< 2	-	< 2	-	150	-	< 100	-	< 10	-	5.5	-
12-07-83	< 2	-	< 2	-	10	-	< 20	-	< 10	-	4	-
03-20-84	< 2	-	< 1	-	60	-	< 20	-	< 10	-	6	-
Capps Creek												
03-30-83	< 4	-	< 2	-	330	-	< 50	-	< 10	-	2.4	-
06-14-83	< 2	< 2	< 2	< 2	170	70	840	< 20	30	< 10	78	< 2
08-24-83	< 2	-	< 2	-	190	-	< 100	-	< 10	-	15	-
12-07-83	< 2	-	< 2	-	20	-	< 20	-	< 10	-	6	-
03-20-84	< 2	-	< 1	-	70	-	50	-	< 10	-	30	-
Middle Creek												
03-31-83	< 4	-	< 2	-	260	-	< 50	-	< 10	-	3.4	-
06-14-83	< 2	< 2	< 2	< 2	80	80	< 20	< 20	< 10	< 10	2	4
08-24-83	< 2	-	< 2	-	170	-	< 100	-	< 10	-	< 2	-
12-07-83	< 2	-	< 2	-	20	-	< 20	-	< 10	-	4	-
03-20-84	< 2	-	< 1	-	40	-	< 20	-	< 10	-	1	-
Lone Creek												
03-31-83	< 4	-	< 2	-	280	-	< 50	-	< 10	-	< 2	-
06-14-83	< 2	< 2	< 2	< 2	95	95	< 20	< 20	< 10	< 10	10	4
08-24-83	< 2	-	< 2	-	170	-	< 100	-	< 10	-	< 2	-
12-07-83	< 2	-	< 2	-	10	-	< 20	-	< 10	-	4	-
03-20-84	< 2	-	< 1	-	60	-	< 20	-	< 10	-	2	-
Chuitna River												
03-31-83	< 4	-	< 2	-	260	-	< 50	-	< 10	-	< 2	-
06-14-83	< 2	< 2	< 2	< 2	60	50	< 20	< 20	< 10	< 10	< 2	[e]6
08-24-83	< 2	-	< 2	-	140	-	< 100	-	< 10	-	< 2	-
12-07-83	< 2	-	< 2	-	10	-	< 20	-	10	-	5	-
03-20-84	< 2	-	< 1	-	60	-	< 20	-	< 10	-	5	-

[e]Contamination suspected.

Appendix C. Nutrient analysis of Beluga water-quality samples.

Date	Time	Streamflow, instantaneous (cfs)	Nitrogen, ammonia + organic total (mg/l as N)	Nitrogen, NO_2 + NO_3 dissolved (mg/l as N)	Nitrogen, ammonia dissolved (mg/l as N)	Phosphorus, total (mg/l as P)	Phosphorus, total reactive (dissolved) (mg/l as P)	Phosphorus, filterable reactive (ortho,dissolved) (mg/l as P)
Bishop Creek								
12-15-82	0935	15	[a]-	0.223	0.023	0.031	0.014	0.012
03-30-83	1230	13	0.10	0.177	0.030	0.029	0.005	0.005
06-14-83	0910	108	0.15	0.541	0.136	[b]0.024	0.088	0.044
08-24-83	0940	28	0.14	0.056	0.005	0.060	0.046	0.029
03-20-84	0930	35	0.17	0.172	0.009	0.025	0.015	0.009
Capps Creek								
12-15-82	1225	8.8	[a]-	0.333	0.016	0.034	0.008	0.008
03-30-83	1420	5.2	0.09	0.292	0.005	0.016	0.015	0.015
06-14-83	1110	157	0.26	0.475	0.033	0.140	0.040	0.030
08-24-83	1105	16	0.13	0.123	0.007	0.056	0.005	0.004
03-20-84	1100	[c]12	0.13	0.351	0.011	0.019	0.007	0.008
Middle Creek								
12-16-82	1225	6.9	[a]-	0.092	0.028	0.021	0.022	0.019
03-31-83	1410	4.3	0.11	0.110	0.021	0.031	0.022	0.021
06-14-83	1350	13	[a]-	0.034	0.012	[a]-	0.010	0.007
08-24-83	1220	9.7	0.19	0.013	0.012	0.019	0.016	0.017
03-20-84	1230	13	0.21	0.049	0.014	0.020	0.012	0.012
Lone Creek								
12-16-82	1100	16	0.11	0.185	0.022	0.017	0.015	0.013
03-31-83	1150	9.6	0.11	0.130	0.017	0.019	0.011	0.010
06-14-83	1515	28	0.16	0.012	0.011	0.021	0.011	0.009
08-24-83	1320	20	0.20	0.025	0.011	0.037	0.013	0.014
03-20-84	1350	14	0.21	0.102	0.019	0.015	0.010	0.010
Chuitna River								
12-16-82	0900	[d]100	[a]-	0.208	0.015	0.021	0.010	0.009
03-31-83	1100	[d]120	0.07	0.171	0.013	0.023	0.011	0.012
06-14-83	1700	[d]470	0.10	0.107	0.013	0.029	0.010	0.009
08-24-83	1445	139	0.14	0.023	0.006	0.010	0.005	0.008
03-20-84	1450	[e]100	0.15	0.130	0.005	0.018	0.011	0.011

[a]Missing data.
[b]Erroneous value suspected.
[c]U.S. Geological Survey (1985, p. 180).
[d]U.S. Geological Survey (1984, p. 159).
[e]U.S. Geological Survey (1985, p. 182).

Appendix D-1. Density (numbers/m²), number of taxa, diversity, and evenness of benthic invertebrates collected in Middle Creek, Beluga coal area, June 15, 1983.

	Site											
	1				2				5			
Taxon	I	II	III	IV	I	II	III	IV	I	II	III	IV
Insecta												
Ephemeroptera												
Unidentified Ephemeroptera	10	60	10	20	80	40	20	50	190	100	70	
Baetis bicaudatus	60	50	180	80	140	480	120	150	70	20	20	
Baetis tricaudatus	110	110	260	100	800	1120	910	740	30	120	80	20
Baetis sp.	130	90	200	90	130	350	80	180	500	1050	430	50
Cinygmula sp.	40	10							10			
Ephemerella doddsi		10	20	20					20	30	50	
Ephemerella infrequens/ E. inermis complex					30	10	30		10		10	
Unidentified Heptageniidae	430	370	620	280	140	220	60	120	170	90	180	70
Plecoptera												
Unidentified Plecoptera					10		10	20				
Unidentified Chloroperlidae	150	190	220	90		10	10		310	230	290	150
Isoperla sp.									10	10		
Unidentified Perlodidae						60						
Zapada cinctipes	20	20	60			20			10			20
Zapada oregonensis	110	140	120	40	30	40		20		10	20	
Trichoptera										10		
Unidentified Trichoptera							10					
Apatania sp.	10				10		60					
Brachycentrus sp.	70	20	400	60		20	30	10	60	100	80	
Glossosoma sp.	30	60	20	40					40	50	10	
Ochrotrichia sp.		90	140	10	10				220	380	300	80
Onocosmoecus sp.					10	10		30				
Unidentified Limnephilidae	50	10		30			20		150	70	160	30
Rhyacophila vepulsa			30									
Rhyacophila sp.	40	60	70	20						10		

Appendix D-1 (cont.)

Taxon	Site 1 I	Site 1 II	Site 1 III	Site 1 IV	Site 2 I	Site 2 II	Site 2 III	Site 2 IV	Site 5 I	Site 5 II	Site 5 III	Site 5 IV
Diptera												
Atherix sp.	10											
Chelifera sp.	10	60	10	10	150	80	20	30			20	
Unidentified Chironomidae	3680	7810	6100	2690	6970	4460	4680	3570	2160	4130	4050	2980
Dicranota sp.	20	20	40	10	120	50	20	40	10	10	20	
Palpomyia sp.	100	50	20	10	80	10		10				
Prosimulium sp.		10	50	20	20	10					10	
Unidentified Simuliidae										20		
Simulium sp.	1440	840	31640	9220	4220	36540	1590	2630	1370	1470	3580	130
Hymenoptera												
Unidentified Hymenoptera								10				
Collembola	10					20	20			30	10	
Turbellaria	10		40	10					30	30		10
Nematoda	90	10		30	100	70	140	30	10			
Oligochaeta	50	30	40	30	830	530	20	40	10	20	10	20
Pelecypoda				40	90	10	10					
Arachnida												
Acarina	550	1020	820	370	340	350	190	650	140	330	150	70
Crustacea												
Ostracoda							10		10	10	20	90
Copepoda				10	60				10			
Total number of invertebrates/m²	7230	11140	41110	13330	14370	44510	8060	8330	5550	8330	9570	3720
Total number of taxa (based on number of insect families and other invertebrates)	19	18	17	21	16	18	16	14	19	19	17	12
Shannon-Weaver Diversity Index	2.40	1.73	1.23	1.50	2.09	1.02	1.84	2.03	2.59	2.31	2.11	1.34
Evenness	0.56	0.42	0.30	0.34	0.52	0.25	0.46	0.53	0.61	0.54	0.52	0.38

Appendix D-2. Density (numbers/m²), number of taxa, diversity, and evenness of benthic invertebrates collected in Middle Creek, Beluga coal area, June 15, 1983.

	Site											
	7				8				11			
Taxon	I	II	III	IV	I	II	III	IV	I	II	III	IV
Insecta												
Ephemeroptera												
Unidentified Ephemeroptera		10			10		10		40	40	70	20
Baetis bicaudatus	50	30	20	20	10		10			10	20	10
Baetis tricaudatus	160	280	200	130	260	140	50		110	60	120	130
Baetis sp.	40	410	250	310	140	310	50	10	50	450	340	500
Ephemerella doddsi	50		40	10					20	50	20	10
Ephemerella infrequens/ *E. inermis* complex				20	10		10		10	10		
Unidentified Heptageniidae	350	380	370	780	230	190	10	10	50	80	70	20
Plecoptera												
Unidentified Plecoptera		20	30	20			20			10		
Unidentified Chloroperlidae	120	310	130	240	220	160	10	10	110	150	80	60
Isoperla sp.				10					50	10		
Unidentified Perlodidae			10		10							20
Zapada cinctipes						10				10		
Zapada oregonensis	20	10	20	30			10			10		
Trichoptera												
Unidentified Trichoptera				10	20				10	20		10
Brachycentrus sp.	60	20	30	20	10	10			30	10		120
Glossosoma sp.	90	30	70	40	20	30			10			10
Ochrotrichia sp.	30	100							130	300	930	1400
Onocosmoecus sp.	10			60	10		10					
Unidentified Limnephilidae	30	20	20	80	30	10				10	10	50
Rhyacophila sp.	10	50	20							20		

Appendix D-2 (cont.)

Taxon	Site 7 I	II	III	IV	Site 8 I	II	III	IV	Site 11 I	II	III	IV
Diptera												
Chelifera sp.		20			10		30		20	20		20
Unidentified Chironomidae	9920	19830	11840	18180	11750	13380	18280	470	660	4130	3000	6230
Dicranota sp.	10	50	40	50	50		10	10	10	20	10	
Palpomyia sp.	110	20	60	350	20		10	20	30	20	10	
Pericoma sp.		20										
Prosimulium sp.	30	130	1060	50	10	60					20	70
Unidentified Simuliidae		20										
Simulium sp.	24470	32030	62110	8400	2670	6820	310	120	820	7760	6460	13830
Holophilus sp.									10			
Collembola	10	10						10				
Turbellaria	70			10		10					10	
Nematoda	80	90	20	440	10	30	10		30		30	20
Oligochaeta	300		30	20	140	1720	100	480	10		10	20
Arachnida												
Acarina	290	360	190	1180	240	50	80	10	50	240	180	260
Crustacea												
Ostracoda	20	10	30					10	10	10	20	50
Copepoda										10		
Total number of invertebrates/m²	36330	54260	76590	30460	15880	22930	19020	1160	2270	13460	11410	22860
Total number of taxa (based on number of insect families and other invertebrates)	20	19	18	17	16	13	14	11	17	18	15	16
Shannon-Weaver Diversity Index	1.30	1.29	0.82	1.69	1.32	1.54	0.33	1.91	2.71	1.65	1.75	1.57
Evenness	0.30	0.30	0.20	0.41	0.33	0.42	0.09	0.55	0.66	0.40	0.45	0.39

Appendix D-3. Density (numbers/m²), number of taxa, diversity, and evenness of benthic invertebrates collected in Middle Creek, Beluga coal area, August 25, 1983.

Taxon	Site 1 I	Site 1 II	Site 1 III	Site 1 IV	Site 2 I	Site 2 II	Site 2 III	Site 2 IV	Site 5 I	Site 5 II	Site 5 III	Site 5 IV
Insecta												
Ephemeroptera												
Baetis bicaudatus						10				160	30	10
Baetis tricaudatus			10	10								10
Baetis sp.	1110	3220	2640	2530	1560	3390	4070	1360	510	1000	440	360
Cinygmula sp.		10	10					10				
Ephemerella doddsi	10	10	60	20		10				40	30	10
Ephemerella infrequens/ E. inermis complex		40		20	130	140	30	20				
Unidentified Heptageniidae	1660	2270	2770	2840	400	580	380	120	110	240	1010	1580
Unidentified Siphlonuridae		40	40	10	40		10	10			10	60
Plecoptera												
Unidentified Capniidae	480	1580	2140	1700	910	880	1340	510	30	240	280	640
Unidentified Chloroperlidae	100	30	50	50					50	40	40	130
Isoperla sp.		10	30								20	
Unidentified Perlodidae	10								10			30
Skwala sp.		10	20	10		20	10	20				
Zapada cinctipes	680	1320	1180	920	900	1830	660	240	80	130	330	150
Zapada oregonensis		10		10	40		10			20	10	
Zapada sp.	180	530	230	400	10	20	10				40	40
Trichoptera												
Apatania sp.	10	20			30	30	130	210				
Brachycentrus sp.	280	130	170	120		10	30	40		20	100	
Ecclisomyia sp.					10				20	10		60
Glossosoma sp.	760	670	640	710	70	190	110	130	110	380	170	110
Unidentified Limnephilidae	20	20	20		10				20	30	20	20
Rhyacophila vepulsa	50	100	90	10								10

Appendix D-3 (cont.)

Taxon	Site 1 I	Site 1 II	Site 1 III	Site 1 IV	Site 2 I	Site 2 II	Site 2 III	Site 2 IV	Site 5 I	Site 5 II	Site 5 III	Site 5 IV
Diptera												
Chelifera sp.	10	10	10		10	10	60					30
Unidentified Chironomidae	5330	7020	12420	5810	7610	5970	10050	12060	350	1230	980	2740
Dicranota sp.	190	60	120	140	410	500	440	210	30	40	50	20
Hesperoconopa sp.										10	10	
Palpomyia sp.	210	120	210	350	260	140	230	40		10	10	50
Pericoma sp	620	680	1130	1320	300	40	30	110		10	370	750
Unidentified Simuliidae	10											
Simulium sp.	10	160	60	70	20	10	10	20				
Unidentified Tipulidae					10							
Tipula sp.								10				20
Hymenoptera												
Unidentified Hymenoptera	10						10					
Collembola			10									
Turbellaria	100	280	310	110	30		10	30	30	40	150	50
Nematoda	40			40	30					10		10
Oligochaeta	90	50	70	610	1260	370	150	210	110	160	960	1530
Pelecypoda					110	10		70		40		
Gastropoda							10					
Arachnida												
Acarina	490	560	670	180	680	660	530	640	70	170	90	330
Crustacea												
Cladocera	10			10	10			10	60	40	10	10
Ostracoda	60	130	640	270	60	40	50	40	30	190	110	360
Copepoda	20	20	10	150	400	30	70	40	10	10	10	10
Total number of invertebrates/m²	12550	19110	25760	18420	15310	14890	18440	16160	1630	4270	5280	9130
Total number of taxa (based on number of insect families and other invertebrates)	25	23	24	23	22	20	23	22	16	21	21	23
Shannon-Weaver Diversity Index	2.97	2.92	2.70	3.12	2.74	2.64	2.19	1.64	3.17	3.11	3.36	3.12
Evenness	0.64	0.65	0.59	0.69	0.61	0.61	0.48	0.37	0.79	0.71	0.77	0.69

Appendix D-4. Density (numbers/m²), number of taxa, diversity, and evenness of benthic invertebrates collected in Middle Creek, Beluga coal area, August 25, 1983.

	Site											
	7				8				11			
Taxon	I	II	III	IV	I	II	III	IV	I	II	III	IV
Insecta												
Ephemeroptera												
Baetis bicaudatus			10			50	30	30		30	10	
Baetis tricaudatus	20		20		30				10		30	
Baetis sp.	2750	2680	4810	2140	3230	2800	1170	3690	260	470	590	270
Epeorus sp.				10								
Ephemerella doddsi	40		20	40	160	90	30	50		250	280	130
Ephemerella infrequens/ E. inermis complex	40		10	10	10	20		60		60	20	30
Unidentified Heptageniidae	1890	2170	810	450	480	1010	320	270		290	460	220
Rhithrogena sp.			10						10	40	110	10
Unidentified Siphlonuridae			20	20	10							10
Plecoptera												
Unidentified Capniidae	1100	1400	420	310	880	700	400	180	60	140	150	220
Unidentified Chloroperlidae	20	80	70	120	80	180	90	10	30	70	80	30
Isoperla sp.	120			40		50						
Unidentified Perlodidae		10	10		40		30	40		90	20	30
Skwala sp.	20			10		10						
Taenionema sp.		10		10						10	10	10
Zapada cinctipes	2490	900	480	660	350	400	70	160	60	740	440	350
Zapada oregonensis	10		40	10			10	20		10		20
Zapada sp.	370	110	130	190	20	20		40	10			40
Trichoptera												
Apatania sp.							20	50				
Brachycentrus sp.	460	130	560	210	150	110		110	30	190	70	110
Ecclisomyia sp.					60		10	60		60		
Glossosoma sp.	670	330	760	1150	110	380	50	300	10	1530	870	140
Unidentified Limnephilidae	60	10	10			20	10		20	30	10	20
Onocosmoecus sp.												10
Psychoglypha sp.	10											
Rhyacophila sp.						10						

Appendix D-4 (cont.)

Taxon	Site 7 I	7 II	7 III	7 IV	Site 8 I	8 II	8 III	8 IV	Site 11 I	11 II	11 III	11 IV
Diptera												
Chelifera sp.	20					10				30	10	
Unidentified Chironomidae	9020	14480	3620	3700	3250	1380	340	530	130	350	680	700
Dicranota sp.	210	210	120	130	290	160	190	260	20	20	60	20
Palpomyia sp.	90	30	30	90	60	30	10	20				20
Pericoma sp.	1800	2930	2910	1900	1250	480	140	30	60	760	420	50
Unidentified Simuliidae									10			
Simulium sp.		30	50	10	40	40		20			40	20
Unidentified Tipulidae					20							
Tipula sp.	10											
Hymenoptera												
Unidentified Hymenoptera	10					10						
Collembola	10				10			10				
Turbellaria	230	40	30	70	20	20	90	20	40	40	610	170
Nematoda		20	20	120	20	10	220	90	10			
Oligochaeta	40	270	170	140	750	80	370	920	60	120	1070	390
Pelecypoda								10		10		
Arachnida												
Acarina	1100	550	430	450	410	150	70	40	30	220	80	100
Crustacea												
Cladocera	60	40	40	30	10				20	80		
Ostracoda	130	130	80	40	80	50	20	20	20	40	40	10
Copepoda	20			30	70				10	50	30	10
Total number of invertebrates/m^2	22820	26560	15690	12090	11890	8270	3690	7040	910	5730	6190	3140
Total number of taxa (based on number of insect families and other invertebrates)	23	21	22	23	24	23	18	22	19	22	21	22
Shannon-Weaver Diversity Index	2.93	2.35	2.88	3.11	3.10	3.11	3.29	2.61	3.51	3.50	3.55	3.60
Evenness	0.65	0.53	0.65	0.69	0.68	0.69	0.79	0.59	0.83	0.78	0.81	0.81

Appendix D-5. Density (numbers/m²), number of taxa, diversity, and evenness of benthic invertebrates collected in Middle Creek, Beluga coal area, June 14, 1984.

	Site											
	1				2				5			
Taxon	I	II	III	IV	I	II	III	IV	I	II	III	IV
Insecta												
Ephemeroptera												
Unidentified												
Ephemeroptera	50	50	20	130	80		50	30	180	330	120	60
Baetis bicaudatus	70	30	80	100	10	30	40	10	320	1050	260	20
Baetis tricaudatus	90	70	150	70	120	110	200	50	110	140	150	130
Baetis sp.		10		60	40		100	30	730	130	10	150
Ephemerella doddsi	10		50						20	130	10	
Ephemerella infrequens/												
E. inermis complex					30							
Unidentified Heptageniidae	460	230	830	460			230	10	330	340	310	160
Plecoptera												
Unidentified Plecoptera			10									
Unidentified												
Chloroperlidae	80	70	320	190		10	20		130	100	110	190
Isoperla sp.	10											
Unidentified Perlodidae			10	10	30	10	60	10				
Zapada cinctipes	30		10	10								
Zapada oregonensis	60	10	20	50								
Trichoptera												
Unidentified Trichoptera			100		70	50	150	20		10		70
Apatania sp.					20	90		10				
Brachycentrus sp.	70	50	60	40						40	10	
Glossosoma sp.	80	70	70	80					300	270	80	10
Ochrotrichia sp.			10		10				340	570	420	760
Onocosmoecus sp.					40	20	20					
Psychoglypha sp.								100				
Unidentified Limnephilidae	20	20		40	150	80		670	90	60	30	90
Rhyacophila vepulsa	30		10									
Rhyacophila sp.										10		

Appendix D-5 (cont.)

Taxon	Site 1 I	1 II	1 III	1 IV	Site 2 I	2 II	2 III	2 IV	Site 5 I	5 II	5 III	5 IV
Diptera												
Chelifera sp.					360	30	50		10	20		
Unidentified Chironomidae	2640	1620	3920	4520	12630	6670	11090	5470	3260	4010	3650	7270
Dicranota sp.	50	10	90	60	190	160	60	10	30			30
Dixa sp.											10	
Palpomyia sp.	290	40	60	240	240	30	30		10		10	250
Prosimulium sp.			20	10								
Simulium sp.	3260	1910	8560	5210	710	280	5820	330	180	120	20	10
Unidentified Tipulidae						10						
Hymenoptera												
Unidentified Hymenoptera	30							10	10			
Turbellaria			30	40	10		30		60	30	10	40
Nematoda	10	20		20	240	110	50	60			10	
Oligochaeta	420	70	30	570	340	870	140	640	130	20	140	790
Pelecypoda					130	20		80				
Gastropoda								10				
Arachnida												
Acarina	110	100	50	340	270	140	320	30	70	240	250	680
Crustacea												
Cladocera		50		40				10	10	30		
Ostracoda	10	20	10	40	220	20	10	50	120	40		100
Copepoda		10		20	30	10			40			30
Total number of invertebrates/m²	7880	4460	14520	12350	15970	8750	18470	7640	6480	7690	5610	10840
Total number of taxa (based on number of insect families and other invertebrates)	19	17	18	19	17	15	15	15	19	17	16	15
Shannon-Weaver Diversity Index	2.35	2.19	1.70	2.17	1.42	1.42	1.46	1.53	2.48	2.30	1.90	1.86
Evenness	0.55	0.54	0.41	0.51	0.35	0.36	0.37	0.39	0.58	0.56	0.48	0.48

Appendix D-6. Density (numbers/m²), number of taxa, diversity, and evenness of benthic invertebrates collected in Lone Creek, Beluga coal area, June 14, 1984.

Taxon	Site 7 I	7 II	7 III	7 IV	8 I	8 II	8 III	8 IV	11 I	11 II	11 III	11 IV
Insecta												
Ephemeroptera												
Unidentified Ephemeroptera	40	10		10	10	30	30	30	280	520	120	180
Baetis bicaudatus	250	320	160		360	670	80	190	200	1500	1360	320
Baetis tricaudatus	40	130	140	70	30	20	80		260	240	150	190
Baetis sp.	30	50	20	130	30	30	130		310	1290	120	190
Cinygmula sp.								60				
Epeorus sp.	10		30									
Ephemerella doddsi		40	10	10	20				30	70	30	50
Ephemerella infrequens/ E. inermis complex		10		10				10	10			10
Unidentified Heptageniidae	740	790	410	520	40	90	150	40	210	260	210	100
Plecoptera												
Unidentified Plecoptera						10			10			
Unidentified Capniidae										10		10
Unidentified Chloroperlidae	150	480	260	120	470	250	390	130	180	510	300	100
Isoperla sp.	20		50			20	10	10	20	10		
Unidentified Perlodidae	30	20		40	40	40	20	30	20			30
Zapada oregonensis	40	20	30			10	10	10				
Trichoptera												
Unidentified Trichoptera	10			20		10	130	50			10	10
Brachycentrus sp.	40	30	30	10		10		40	70	70	30	80
Glossosoma sp.	260	350	60	20	90	70	70	260	10	40		10
Ochrotrichia sp.					10		10		250	950	660	240
Onocosmoecus sp.	20						20	60				
Psychoglypha sp								20				
Unidentified Limnephilidae			10	30		10	160	420	30		10	10
Rhyacophila sp.									10			

Appendix D-6 (cont.)

Taxon	Site 7 I	7 II	7 III	7 IV	Site 8 I	8 II	8 III	8 IV	Site 11 I	11 II	11 III	11 IV
Diptera												
Chelifera sp.		10					10	10	20			
Unidentified Chironomidae	4790	7710	5640	8300	7850	8800	13250	8410	3310	4680	3320	7040
Dicranota sp.	60	20	40		40		20	30	30	60	40	10
Palpomyia sp.	170	50	60	70	10		10	10	10	20	10	40
Prosimulium sp.			20	10		20						
Simulium sp.	12770	8680	34050	3970	2570	16120	570	330	1610	910	1420	1440
Hymenoptera												
Unidentified Hymenoptera		10								10		
Collembola	10											
Turbellaria	70	10	10		60	10	50	20	50			20
Nematoda	240	90	70	40	140	180	60	30	20		30	30
Oligochaeta	260	30	10	40	990	420	500	520	90	310		30
Pelecypoda		10		30			20					
Arachnida												
Acarina	180	110	70	230	20	20	250	130	280	180	90	190
Crustacea												
Cladocera									110	160	10	40
Ostracoda		20	10	20		10	20	10	30	80	60	80
Copepoda					20				80	40	20	10
Total number of invertebrates/m²	20230	19000	41190	13780	12800	26850	16050	10860	7540	11920	8000	10460
Total number of taxa (based on number of insect families and other invertebrates)	17	20	18	16	16	15	19	19	22	19	16	21
Shannon-Weaver Diversity Index	1.72	1.83	0.90	1.58	1.82	1.41	1.19	1.47	2.59	2.55	2.38	1.75
Evenness	0.42	0.42	0.22	0.39	0.45	0.36	0.28	0.35	0.58	0.60	0.59	0.40

Appendix D-7. Density (numbers/m^2), number of taxa, diversity, and evenness of benthic invertebrates collected in Middle Creek, Beluga coal area, August 29, 1984.

Taxon	Site 1 I	Site 1 II	Site 1 III	Site 1 IV	Site 2 I	Site 2 II	Site 2 III	Site 2 IV	Site 5 I	Site 5 II	Site 5 III	Site 5 IV
Insecta												
Ephemeroptera												
Baetis sp.	570	710	320	70	430	630	340	230	280	500	560	210
Cinygma sp.											10	10
Ephemerella doddsi	30			20					70	200	80	20
Ephemerella infrequens/ E. inermis complex				20	10		10		10		40	20
Unidentified Heptageniidae	250	390	200	100	180	480	550	120	560	1230	750	1010
Rhithrogena sp.									60	20	10	10
Unidentified Siphlonuridae				10			20		10	10	40	10
Plecoptera												
Unidentified Plecoptera					10							
Unidentified Capniidae	380	1450	420	790	540	600	480	490	120	190	180	770
Unidentified Chloroperlidae	90	70	10	90			20		50	80	10	100
Isoperla sp.									10	20	10	
Unidentified Perlodidae									10			
Skwala sp.					40	30	10					
Zapada cinctipes	90	60	110	40	310	530	310	10	30	320	870	170
Zapada oregonensis			20							40		
Zapada sp.	40	40	40		10	20				20	40	20
Trichoptera												
Unidentified Trichoptera		20	10	10	40	10	20			10		
Apatania sp.	10	10		10	350	240	80	90				
Brachycentrus sp.	10	20	20			20	10		190	310	140	
Ecclisomyia sp.	60			70	20				30	40	100	10
Glossosoma sp.	800	620	480	280	100	40	40	30	1560	3620	1030	740
Arctopsyche sp.									10	10	10	
Psychoglypha sp.										10	10	
Unidentified Limnephilidae	30	30	30	20	30			10	10	30	140	
Rhyacophila vepulsa		10	10								50	10
Rhyacophila sp.			10						10	10		

Appendix D-7 (cont.)

Taxon	Site 1 I	Site 1 II	Site 1 III	Site 1 IV	Site 2 I	Site 2 II	Site 2 III	Site 2 IV	Site 5 I	Site 5 II	Site 5 III	Site 5 IV
Diptera												
Chelifera sp.			10	10	230	40	20	20	30	120	10	
Unidentified Chironomidae	2300	5170	1880	2430	9900	15980	8770	7230	1980	2890	1480	1140
Dicranota sp.	30	70		10	190	280	250	170	80	120	20	10
Hesperoconopa sp.		10								30	10	
Palpomyia sp.	440	220	130	290	1740	1610	430	90	20	30	10	280
Pericoma sp.	100	260	230	120	1120	1560	970	140	440	2020	200	400
Prosimulium sp.										10	10	
Simulium sp.	130	60	40	20				10	10	10		
Tipula sp.						30						
Hymenoptera												
Unidentified Hymenoptera		10			10			20	10			
Collembola								20	30			
Turbellaria	50	120	20	10				20	60	60	240	30
Nematoda	50	10			320	20	30			10		
Oligochaeta	260	240	50	80	270	140	250	40	90	130	180	320
Pelecypoda					620		50	30				
Gastropoda					20		10	10				
Arachnida												
Acarina	760	670	450	30	550	790	390	580	240	610	70	40
Crustacea												
Cladocera		10		10	40		10	40	130	80	20	100
Ostracoda	70	80	20	20	480	130	110	350	390	280	20	60
Copepoda	180	380	100	100	910	220	50	20	130	10		40
Total number of invertebrates/m²	6730	10740	4610	4660	18470	23400	13230	9770	6660	13080	6350	5530
Total number of taxa (based on number of insect families and other invertebrates)	20	22	19	21	22	18	24	22	27	26	24	20
Shannon-Weaver Diversity Index	3.28	2.77	2.99	2.54	2.72	1.95	2.11	1.71	3.29	3.16	3.39	3.32
Evenness	0.76	0.62	0.70	0.58	0.61	0.47	0.46	0.38	0.69	0.67	0.74	0.77

Appendix D-8. Density (numbers/m^2), number of taxa, diversity, and evenness of benthic invertebrates collected in Lone Creek, Beluga coal area, August 29, 1984.

Taxon	Site 7 I	7 II	7 III	7 IV	Site 8 I	8 II	8 III	8 IV	Site 11 I	11 II	11 III	11 IV
Insecta												
Ephemeroptera												
Baetis sp.	900	790	360	280	470	660	590	150	130	350	420	270
Cinygma sp.												10
Ephemerella doddsi	20	20	40	40		10	20		40	70	100	10
Ephemerella infrequens/ *E. inermis* complex		10	10		10			30	30	20		20
Unidentified Heptageniidae	380	560	510	470	180	790	30	80	540	190	230	190
Rhithrogena sp.							10		40	40	50	10
Unidentified Siphlonuridae		20		10	10				10		20	
Plecoptera												
Unidentified Capniidae	790	1360	730	630	1000	2230	90	210	920	40	110	580
Unidentified Chloroperlidae	20	160	120	170	100	140	30		200	70	90	70
Isoperla sp.	20	10				10	20	10		30	30	
Pteronarcella badia									10	10	10	
Skwala sp.		10		10				30				
Zapada cinctipes	890	400	110	170	60	330	10	40	270	540	130	60
Zapada oregonensis		10	20								10	
Zapada sp.	120			30	20	20	10	20				
Trichoptera												
Apatania sp.	20	20	50	100		20	930	310				
Brachycentrus sp.	120	40	40	170	20	50	40	10	20	40	80	
Ecclisomyia sp.				10				20				
Glossosoma sp.	270	440	470	660	200	840	1180	630	380	140	420	30
Psychoglypha sp.			10									
Unidentified Limnephilidae	20	30	10				10		10			10

Appendix D-8 (cont.)

Taxon	Site 7 I	Site 7 II	Site 7 III	Site 7 IV	Site 8 I	Site 8 II	Site 8 III	Site 8 IV	Site 11 I	Site 11 II	Site 11 III	Site 11 IV
Diptera												
Chelifera sp.	10	10	10					20	50	40	20	
Unidentified Chironomidae	4950	21550	10640	15560	1240	3540	830	1900	1890	380	1440	770
Dicranota sp.	220	230	170	440	240	250	70	50	380	80	260	10
Palpomyia sp.	680	390	330	490	200	180			20		10	120
Pericoma sp.	1390	2180	2650	1610	120	1060	10	30	2310	150	760	210
Simulium sp.	60	120	60			30			20	20	40	
Collembola				10					10		10	10
Turbellaria	60	40	120	40	40	60			80	20	10	90
Nematoda	1160	70	20	20		10	270	190			20	20
Oligochaeta	320	40	40	60	290	510	210	180	330	40	300	840
Pelecypoda				10		10		10	10	10		
Arachnida												
Acarina	880	1020	500	800	130	470	150	400	530	140	370	90
Crustacea												
Cladocera	70	30	40	50	20	110	30	10	70	80	120	80
Ostracoda	330	300	60	500	90	210		10	460	190	160	170
Copepoda	40	710	40	40	20	60	20		120	30	10	40
Total number of invertebrates/m^2	13740	30570	17160	22380	4460	11600	4560	4340	8880	2720	5230	3710
Total number of taxa (based on number of insect families and other invertebrates)	23	24	22	24	19	23	18	19	25	22	25	20
Shannon-Weaver Diversity Index	3.28	1.91	2.14	1.98	3.25	3.25	2.99	2.84	3.38	3.74	3.56	3.36
Evenness	0.72	0.42	0.48	0.43	0.76	0.73	0.72	0.67	0.73	0.84	0.77	0.78

Appendix E. Three-factor analysis of variance table, where the variable is benthic-invertebrate abundance (in numbers/meter^2) during June and August 1983 and 1984, in Middle and Lone Creeks, Beluga coal area, Alaska. The number of samples used in this analysis = 96.

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	Calculated F	Critical F [a]	Conclusion
stream	1	0.038	0.038	0.587	$F_{0.05[1,72]} = 4.00$	Accept H_o
site	2	3.023	1.511	23.182	$F_{0.05[2,72]} = 3.15$	Reject H_o
date	3	0.607	0.202	3.106	$F_{0.05[3,72]} = 2.76$	Reject H_o
stream X site	2	1.299	0.649	9.963	$F_{0.05[2,72]} = 3.15$	Reject H_o
stream X date	3	0.536	0.179	2.742	$F_{0.05[3,72]} = 2.76$	Accept H_o
site X date	6	0.718	0.120	1.836	$F_{0.05[6,72]} = 2.25$	Accept H_o
stream X site X date	6	0.361	0.060	0.923	$F_{0.05[6,72]} = 2.25$	Accept H_o

[a] There are no critical values for $v_2 = 72$, so the values for the next lowest degrees of freedom, $v_2 = 60$, were used.

Appendix F. Wet-weight biomass (grams/m²) of benthic invertebrates collected from sites in Middle and Lone Creeks, Beluga coal area, during June and August 1983 and 1984. Biomass is summed for each stream, site and month.

		Wet-weight Biomass (grams/m²)							
		Middle Creek site				Lone Creek site			
Month	Sample	1	2	5		7	8	11	
June 1983	I	6.73	12.45	6.94		18.71	14.12	5.36	
	II	8.17	16.61	5.28		21.21	31.05	11.45	
	III	18.75	6.87	11.99		40.88	19.46	7.99	
	IV	9.78	8.78	4.13		24.69	6.04	18.73	
		Σ 43.43	44.71	28.34	116.48	105.49	70.67	43.53	219.69
August 1983	I	9.40	7.41	3.13		14.01	10.64	3.08	
	II	9.41	10.73	6.31		8.79	11.01	21.78	
	III	9.90	8.81	7.08		14.77	7.35	11.13	
	IV	7.78	11.32	8.25		8.64	15.25	5.90	
		Σ 36.49	38.27	24.77	99.53	46.21	44.25	41.89	132.35
June 1984	I	9.89	13.41	7.77		17.11	17.60	9.99	
	II	5.62	11.57	14.47		20.49	26.09	13.17	
	III	12.77	11.25	6.47		23.67	16.81	10.05	
	IV	7.51	7.83	5.83		10.95	21.61	12.74	
		Σ 35.79	44.06	34.54	114.39	72.22	82.11	45.95	200.28
August 1984	I	10.11	6.84	8.46		6.07	5.40	9.11	
	II	8.41	8.88	12.72		8.25	12.08	4.86	
	III	7.18	5.51	7.73		8.20	10.51	6.96	
	IV	6.24	3.79	4.59		9.03	6.65	3.78	
		Σ 31.94	25.02	33.50	90.46	31.55	34.64	24.71	90.90
		Σ 147.65	152.06	121.15	420.86	255.47	231.67	156.08	643.22

Appendix G-1. Habitat parameters at benthic-invertebrate sampling sites.
June 15, 1983

Middle Creek

	Site 1	Site 2	Site 5
Time	1250	1140	1021
Water temperature (°C)	10.3	10.6	10.4
Stream width (ft)	8.0	12.0	12.0
Riparian habitat (%)			
Conifers	-	-	10
Deciduous trees	-	-	40
Shrubs/brush	20	-	40
Grasses	80	100	10

	Site 1				Site 2				Site 5			
Benthos Collection Point	I	II	III	IV	I	II	III	IV	I	II	III	IV
Stream substrate composition (%)												
Boulder	-	-	-	-	-	-	-	-	-	-	-	-
Rubble	20	50	40	40	-	-	-	-	60	70	40	70
Gravel	80	50	60	50	80	90	60	80	40	30	60	30
Sand/silt	-	-	-	10	20	10	40	20	-	-	-	-
Water depth (ft)	0.15	0.15	0.2	0.2	0.15	0.1	0.5	0.55	0.7	0.7	0.3	0.3
Water velocity (ft/sec)	1.45	1.34	1.33	1.62	0.80	[a]-	1.65	1.38	2.51	1.70	0.59	0.64

Lone Creek

	Site 7	Site 8	Site 11
Time	1417	1602	0905
Water temperature (°C)	10.2	12.8	10.5
Stream width (ft)	16.0	18.0	16.5
Riparian habitat (%)			
Conifers	-	-	10
Deciduous trees	-	10	30
Shrubs/brush	60	70	60
Grasses	40	20	-

	Site 7				Site 8				Site 11			
Benthos Collection Point	I	II	III	IV	I	II	III	IV	I	II	III	IV
Stream substrate composition (%)												
Boulder	-	-	-	-	-	-	-	-	-	-	-	-
Rubble	50	70	70	40	-	-	-	-	-	40	45	60
Gravel	40	30	30	60	80	70	80	100	90	60	45	40
Sand/silt	10	-	-	-	20	30	20	-	10	-	10	-
Water depth (ft)	0.4	0.3	0.35	0.3	0.4	0.3	0.3	0.5	0.3	0.7	0.9	0.7
Water velocity (ft/sec)	2.16	1.30	1.70	0.83	1.28	0.75	2.50	0.24	0.95	2.74	2.16	2.74

[a] Missing data.

Appendix C-2. Habitat parameters at benthic-invertebrate sampling sites.
August 25, 1983

Middle Creek

	Site 1				Site 2				Site 5			
Time	1318				1210				1046			
Water temperature (°C)	8.8				8.7				7.8			
Stream width (ft)	8.0				11.0				12.0			
Riparian habitat (%)												
Conifers	-				-				10			
Deciduous trees	-				-				40			
Shrubs/brush	-				-				30			
Grasses	100				100				20			
Benthos Collection Point	I	II	III	IV	I	II	III	IV	I	II	III	IV
Stream substrate composition (%)												
Boulder	-	-	-	-	-	-	-	-	-	80	50	50
Rubble	-	30	30	-	-	-	-	-	70	-	30	25
Gravel	80	70	70	100	100	100	100	100	30	20	20	25
Sand/silt	20	-	-	-	-	-	-	-	-	-	-	-
Water depth (ft)	0.2	0.2	0.2	0.1	0.1	0.1	0.25	0.7	0.8	0.7	0.25	0.25
Water velocity (ft/sec)	0.50	0.85	0.95	0.38	0.57	0.64	1.36	1.30	1.35	0.87	0.59	0.33

Lone Creek

	Site 7				Site 8				Site 11			
Time	1455				1616				0910			
Water temperature (°C)	11.0				11.3				8.2			
Stream width (ft)	14.0				17.0				16.0			
Riparian habitat (%)												
Conifers	-				-				10			
Deciduous trees	10				10				20			
Shrubs/brush	70				70				70			
Grass	20				20				-			
Benthos Collection Point	I	II	III	IV	I	II	III	IV	I	II	III	IV
Stream substrate composition (%)												
Boulder	50	-	30	-	-	-	-	-	-	-	-	-
Rubble	40	40	20	40	-	20	40	70	-	80	100	90
Gravel	-	60	50	60	90	70	60	30	100	20	-	-
Sand/silt	10	-	-	-	10	10	-	-	-	-	-	-
Water depth (ft)	0.3	0.3	0.35	0.3	0.3	0.1	0.2	0.3	0.33	0.58	0.58	0.42
Water velocity (ft/sec)	1.25	0.80	1.36	1.59	1.95	1.59	1.43	2.50	1.92	2.86	1.58	0.80

Appendix G-3. Habitat parameters at benthic-invertebrate sampling sites. June 14, 1984.

Middle Creek

	Site 1	Site 2	Site 5
Time	1145	1050	0944
Water temperature (°C)	11.1	10.6	9.9
Stream width (ft)	8.0	10.0	16.0
Riparian habitat (%)			
Conifers	-	-	10
Deciduous trees	-	-	50
Shrubs/brush	50	-	30
Grasses	50	100	10

	Site 1				Site 2				Site 5			
Benthos Collection Point	I	II	III	IV	I	II	III	IV	I	II	III	IV
Stream substrate composition (%)												
Boulder	-	-	-	-	-	-	-	-	-	-	90	-
Rubble	40	60	30	50	-	-	100	40	80	90	10	70
Gravel	60	40	70	50	50	50	-	-	20	10	-	30
Sand/silt	-	-	-	-	50	50	-	60	-	-	-	-
Water depth (ft)	0.25	0.25	0.25	0.2	0.5	0.45	0.25	0.15	0.9	0.5	0.45	0.3
Water velocity (ft/sec)	1.1	1.0	1.3	1.6	1.1	0.4	1.2	0.8	1.4	1.8	0.7	0.4

Lone Creek

	Site 7	Site 8	Site 11
Time	1230	1330	0840
Water temperature (°C)	12.0	12.4	10.2
Stream width (ft)	16.0	12.0	20.0
Riparian habitat (%)			
Conifers	-	-	-
Deciduous trees	-	20	80
Shrubs/brush	70	70	20
Grass	30	10	-

	Site 7				Site 8				Site 11			
Benthos Collection Point	I	II	III	IV	I	II	III	IV	I	II	III	IV
Stream substrate composition (%)												
Boulder	-	-	-	-	-	-	-	-	-	-	-	-
Rubble	80	90	70	-	50	50	-	40	40	90	100	90
Gravel	20	10	30	80	40	40	100	40	40	10	-	10
Sand/silt	-	-	-	20	10	10	-	20	20	-	-	-
Water depth (ft)	0.25	0.35	0.3	0.6	0.5	0.6	0.6	0.45	0.6	0.6	0.8	0.4
Water velocity (ft/sec)	1.1	0.7	1.8	1.1	1.7	1.9	1.4	1.1	1.4	1.7	2.0	1.1

Appendix C-4. Habitat parameters at benthic-invertebrate sampling sites. August 29, 1984.

Middle Creek

	Site 1				Site 2				Site 5			
Time	1450				1410				1300			
Water temperature (°C)	7.2				7.0				6.6			
Stream width (ft)	8.0				12.0				16.0			
Benthos Collection Point	I	II	III	IV	I	II	III	IV	I	II	III	IV
Stream substrate composition (%)												
Boulder	-	-	-	-	-	-	-	-	-	80	100	-
Rubble	40	40	60	80	-	-	-	-	95	10	-	50
Gravel	60	50	40	20	90	100	100	80	5	10	-	40
Sand/silt	-	10	-	-	10	-	-	20	-	-	-	10
Water depth (ft)	0.5	0.55	0.25	0.2	0.2	0.2	0.25	0.8	0.6	0.55	0.4	0.2
Water velocity (ft/sec)	1.2	0.2	1.2	0.2	0.7	1.2	1.3	0.6	1.0	0.9	0.3	0.2

Lone Creek

	Site 7				Site 8				Site 11			
Time	0930				1040				1140			
Water temperature (°C)	5.5				6.4				6.4			
Stream width (ft)	18.0				12.0				20.0			
Benthos Collection Point	I	II	III	IV	I	II	III	IV	I	II	III	IV
Stream substrate composition (%)												
Boulder	-	-	-	-	-	-	-	-	-	-	-	-
Rubble	90	100	80	80	50	60	40	-	70	100	90	70
Gravel	10	-	20	10	50	40	60	60	30	-	10	30
Sand/silt	-	-	-	10	-	-	-	40	-	-	-	-
Water depth (ft)	0.3	0.3	0.3	0.45	0.2	0.5	0.45	0.4	0.25	0.3	0.6	0.2
Water velocity (ft/sec)	0.8	0.5	1.4	0.8	1.0	1.2	1.2	0.6	1.1	2.0	2.1	0.5